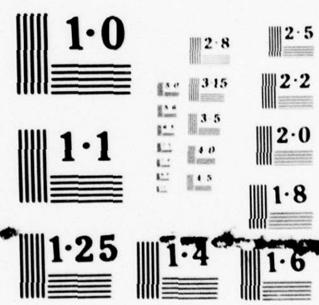
AD-A065 988 KAMAN AEROSPACE CORP BLOOMFIELD CONN F/G 1/3
DRIVESHAFT ALIGNMENT INDICATOR.(U)
JAN 79 F A BILL, R B BOSSLER DAAJ02-77-C-0006
UNCLASSIFIED R-1547 USARTL-TR-79-3 NL

1 OF 2
ADA
065988



NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

LEVEL II

USARTL-TR-79-3

AD A0 65988

DRIVESHAFT ALIGNMENT INDICATOR

Frank A. Bill, Robert B. Bossler, Jr.
KAMAN AEROSPACE CORPORATION
Old Windsor Road
Bloomfield, Conn. 06002

DDC FILE COPY

January 1979

Final Report for Period November 1975 - May 1978

Approved for public release;
distribution unlimited.

Prepared for

APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

The program reported herein is part of a continuing effort of the Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), to conduct investigations directed toward improving inspection and maintenance procedures on Army helicopters. The objective of this program was to facilitate engine transmission alignment by providing an improved static alignment procedure and dynamic alignment capabilities which permit in-flight measurement. The results presented in this report demonstrate that there is an alignment problem with the UH-1/AH-1 fleet. Of 31 UH-1/AH-1 helicopters checked, 61 percent exceeded specified limits. These helicopters had been previously aligned with the current technique. The next step in the development of the improved alignment procedure would be to militarize the DSAI; however, no work is planned by this laboratory.

The technical monitor for this contract was Mr. Meyer B. Salomonsky, Aeronautical Systems Division.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

19

1. REPORT NUMBER 18 USARTL-TR-79-3	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 DRIVESHAFT ALIGNMENT INDICATOR		5. TYPE OF REPORT & PERIOD COVERED 9 Final Technical Report November 1975-May 1978
		6. PERFORMING ORG. REPORT NUMBER 14 R-1547
7. AUTHOR(s) 10 Frank A. Bill, Robert B. Bossler, Jr		8. CONTRACT OR GRANT NUMBER(s) 15 DAAJ02-77-C-0006
9. PERFORMING ORGANIZATION NAME AND ADDRESS Kaman Aerospace Corporation Old Windsor Road Bloomfield, Connecticut 06002		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 17 62209A 1L262209AH76 00 182 EK
11. CONTROLLING OFFICE NAME AND ADDRESS Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia 23604		12. REPORT DATE 11 January 1979
		13. NUMBER OF PAGES 116
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 117p.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Driveshaft Alignment
Coupling Misalignment
Helicopters
UH-1
AH-1

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this program was to reduce the difficulty of driveshaft alignment and to improve dynamic alignment by allowing inflight measurement on Army UH-1/AH-1 helicopters. Under Contract DAAJ02-76-C-0010, a first-concept driveshaft alignment indicator was investigated. The program included ground and flight tests on an Army UH-1 helicopter. A second-generation concept was evolved which indicated improved accuracy and greatly reduced

Cont

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

404362 VB

79 03 19 119

20. ABSTRACT

Cont'

system cost. The second-generation concept was investigated under Contract DAAJ02-77-C-0006. The investigation included design and manufacture of a prototype alignment-measuring tool, ground and flight tests, and a survey of the existing driveshaft alignments of Army helicopters. The survey included eight UH-1 at Bradley Field, Connecticut, ten UH-1 at Felker Field, Fort Eustis, Virginia, and ten UH-1 at Simmons Field, Fort Bragg, North Carolina. Subsequently, three AH-1 were measured at Felker Field, and finally a UH-1 with sling load was measured at Kaman. The significant measurements were static alignment, hover at a 5-foot skid height, and low-speed high-power climb (70 knots forward speed, 1000 ft/minute climb). Statistical analysis of the test data indicates that 99.73 percent ($\pm$ 3σ) of the Army UH-1 fleet has a driveshaft misalignment of 4.96° or less during the highest steady state condition (low-speed high-power climb). This steady state misalignment can be reduced to less than 1.5° by specifying appropriate and attainable alignment limits for hover at a 5-foot skid height. Further, alignment checks can be more easily performed with the tool and procedure described herein than with the standard procedure of TM55-1520-210-20. It is recommended that an evaluation quantity of driveshaft alignment tools be procured as a first step toward improving the driveshaft alignment of Army UH-1/AH-1 helicopters.

PREFACE

The Applied Technology Laboratory of the U.S. Army Research and Technology Laboratories (AVRADCOM) supervises research programs aimed at improving the maintainability of current and future Army helicopters. The alignment of driveshafts in helicopters has been identified as a maintenance problem area. In particular, the alignment procedure for the main driveshaft of the UH-1 has been found to be very difficult and time consuming. Accordingly, a driveshaft alignment indicator was investigated under Contract DAAJ02-76-C-0010. Technical direction was provided by Mr. R. Prather, Aerospace Engineer at the Applied Technology Laboratory. The final report was not published and remaining funds were deobligated because a second-generation concept was evolved which indicated improved accuracy and greatly reduced system cost. The second-generation concept was investigated under Contract DAAJ02-77-C-0006. Technical direction was provided by Mr. M. B. Salomonsky, Aerospace Engineer, Applied Technology Laboratory. This report covers work performed under both contracts, including design and manufacture of a prototype Army maintenance tool suitable for use on the UH-1/AH-1, ground and flight tests, and a field survey to measure actual driveshaft alignment in Army helicopters. The work was accomplished during the periods from 12 November 1975 to 7 June 1976 and from 23 December 1976 to 19 June 1978. The work was conducted at Kaman Aerospace Corporation, Bloomfield, Connecticut under the technical supervision of Mr. Frank A. Bill and Mr. Paul J. Meiselman of the Mechanical Test Group. Overall cognizance of the program was maintained by Mr. Robert B. Bossler, Jr., Chief of Mechanical Systems Research.

TABLE OF CONTENTS

Section	Page
PREFACE	3
LIST OF ILLUSTRATIONS	5
LIST OF TABLES	10
INTRODUCTION	11
DRIVESHAFT ALIGNMENT INDICATOR DESIGN DESCRIPTION	13
PROTOTYPE VERIFICATION	23
DRIVESHAFT ALIGNMENT PROCEDURE INVESTIGATION	34
FIELD SURVEY	42
FIELD SURVEY AT BRADLEY FIELD	42
FIELD SURVEY AT FELKER FIELD	42
FIELD SURVEY AT SIMMONS FIELD	45
FIELD SURVEY OF AH-1 AIRCRAFT AT FELKER FIELD	45
UH-1 EVALUATION WITH SLING LOAD AT KAMAN	45
FIELD SURVEY OBSERVATIONS	53
STATISTICAL ANALYSIS OF FIELD SURVEY DATA	68
CONCLUSIONS	73
RECOMMENDATIONS	73
APPENDIXES	
A DRIVESHAFT ALIGNMENT PER TM55-1520-210-20	74
B BELL HELICOPTER COMPANY SERVICE BULLETIN NO. 205-76-9	87
C PROCEDURE FOR USING THE DRIVESHAFT ALIGNMENT INDICATOR	91

PRECEDING PAGE BLANK

LIST OF ILLUSTRATIONS

Figure		Page
1	Strut Installation - Schematic	14
2	Driveshaft Alignment Indicator Installation - Schematic	15
3	A-Frame Mount	16
4	Power Supply/Demodulator Box	17
5	Digital Readout Box	18
6	Strut Assemblies Installed in a UH-1H Helicopter. Upper Half of Induction Baffle is Omitted for Clarity	19
7	Strut Assemblies Installed in an AH-1 Helicopter	20
8	Forward Coupling Angle Measurement - Baseline System	24
9	Ground and Hover Alignments, Forward C.G. (Station 133), 8600 Lbs G.W.	26
10	Forward Flight Alignments, Forward C.G. (Station 133), 8600 Lbs G.W.	27
11	Descent and Climb Alignments, Forward C.G. (Station 133), 8600 Lbs G.W.	28
12	Bank Angle Alignments, Forward C.G. (Station 133), 8600 Lbs G.W.	29
13	Ground and Hover Alignments, Aft C.G. (Station 138), 8600 Lbs G.W.	30
14	Forward Flight Alignments, Aft C.G. (Station 138), 8600 Lbs G.W.	31
15	Descent and Climb Alignments, Aft C.G. (Station 138), 8600 Lbs G.W.	32
16	Bank Angle Alignments, Aft C.G. (Station 138), 8600 Lbs G.W.	33

LIST OF ILLUSTRATIONS (continued)

Figure		Page
17	Shim Location and Identification.............	35
18	Leg "A" Shim Curve...........................	36
19	Leg "B" Shim Curve...........................	36
20	Leg "C" Shim Curve...........................	37
21	Leg "D" Shim Curve...........................	37
22	Leg "E" Shim Curve...........................	38
23	Leg "F" Shim Curve...........................	38
24	Driveshaft Alignment Chart with Shimming Instructions................................	39
25	Forward Coupling Vertical Angle During Descent and Climb, Forward and Aft C.G., 8600 Lbs G.W...............................	40
26	Forward Coupling Horizontal Angle During Descent and Climb, Forward and Aft C.G., 8600 Lbs G.W...............................	41
27	Forward Coupling Alignment Chart.............	43
28	Eight UH-1 Helicopters Flown at Bradley Field	44
29	Ten UH-1 Helicopters Flown at Felker Field...	46
30	UH-1 Flown Before and After Alignment Change - Felker Field.............................	47
31	Ten UH-1 Helicopters Flown at Simmons Field..	48
32	Three AH-1 Helicopters Flown at Felker Field.	49
33	Army UH-1H With a 2000-Pound Sling Load......	52
34	Engine Mount Installation....................	54
35	Average Current Alignment for Three Conditions and Maximum Expected Misalignment......	70
36	Improved Alignment Possible for Three Conditions and Maximum Expected Misalignment......	72

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
A1	Fairing, Cowling, and Access Panels	79
A2	Engine Air Intake Filters	79
A3	Induction Baffle Installation	80
A4	Particle Separator, Self-Purging Type	81
A5	Maintenance Hoist	82
A6	Leveling Main Transmission	83
A7	Use of Existing Alignment Tool Set	84
A8	Forward Firewall and Bellmouth Assembly	85
A9	Aft Firewall	86
C1	Driveshaft Alignment Indicator Installation	95
C2	Fairing, Cowling, and Access Panels	96
C3	Engine Air Intake Filters	96
C4	Particle Separator, Self-Purging Type	97
C5	Induction Baffle Installation	98
C6	Driveshaft Alignment Chart with Shimming Instructions	99
C7	Forward Firewall and Bellmouth Assembly	100
C8	Aft Firewall	101
C9	A-Frame Mount	102
C10	Transmission Mount Plate	103
C11	Modified Baffle Assembly	104
C12	Strut Assemblies	105
C13	Helicopter Wiring Polarity Checker	106

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
C14	Power Supply/Demodulator Box	107
C15	Digital Readout Box	108
C16	Mount Plate Installed, Particle Separator and Induction Baffle Removed	109
C17	Lower Half of Modified Induction Baffle Installed	110
C18	Lower Half of Particle Separator Installed	111
C19	A-Frame Mounted on Upper Half of Particle Separator	112
C20	Particle Separator with A-Frame Installed, Dogleg Installation	113
C21	Top Screen Assembly Installed	114
C22	Horizontal Strut Assembly Installed	115
C23	Upper Half of Modified Baffle Installed, Vertical Strut Assembly Installed	116

LIST OF TABLES

		Page
1	SHIM THICKNESS AND FORWARD COUPLING ALIGNMENT	35
2	SLING-LOAD TEST DATA	51
3	FIELD SURVEY DATA	57
4	ANGLES AND ANALYSIS FOR THREE CONDITIONS	69
5	CHANGE IN ANGLES AND ANALYSIS	71

INTRODUCTION

Measuring alignment in flight (dynamically) is estimated to be 10 times as valuable as measuring alignment statically. If the dynamic misalignments can be readily measured during various flight regimes, alignment can be ground-adjusted to provide the best operational compromise. Otherwise, static alignment must be based on estimated dynamic behavior. Accurate dynamic measurement would allow precise offsets for each individual helicopter, and different offsets when the same driveshaft is used for different aircraft (UH-1 vs. AH-1).

The specific problem of alignment of the main driveshaft of the UH-1 helicopter was rated in USAAMRDL TR 72-11B[1]. The driveshaft alignment problem on the UH-1 was rated as high for the safety factor and medium for the factors of maintenance workload and helicopter availability.

The current UH-1 driveshaft alignment procedure is given in TM55-1520-210-20[2]. That procedure is reproduced in Appendix A. Main driveshaft alignment is checked statically using a set of special mechanical tools. Prior to the check, four jacks and a depth micrometer are used to position and hold the soft-mounted transmission parallel to its supporting structure. The lift link must also be unloaded by these jacks.

With the driveshaft removed, an extendable plug gage assembly is attached to the engine output. The plug serves to extend the rotational centerline of the engine output to a target plate mounted on the transmission input. An eccentrically located hole in the target plate will accept the plug gage if the vertical and lateral position of the transmission is correct. Nonparallelism of the rotational centerlines of the engine output and the transmission input is checked next, by attaching a dial indicator to the extendable plug gage assembly and trammelling the surface of the target plate which is perpendicular to the transmission input quill. It is required that the transmission be statically rotated CCW when viewed from above and offset to the right and lowered with respect to the engine centerline.

---

1. Clark, M. W., Krauss, W. K., Ciccotti, J. M., IDENTIFICATION AND ANALYSIS OF ARMY HELICOPTER RELIABILITY AND MAINTAINABILITY PROBLEMS AND DEFICIENCIES, VOLUME II, American Power Jet Company: USAAMRDL Technical Report 72-11B, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, April 1972, AD 901457L.

2. Technical Manual, TM55-1520-210-20, ORGANIZATION MAINTENANCE MANUAL, ARMY MODEL UH-1D/H HELICOPTERS, Department of the Army, Washington, D.C., 10 September 1971.

Main driveshaft alignment is altered by selectively shimming between one or more of the engine tubular mounts and the engine deck, thereby shifting the position of the engine.

The existing alignment tool provides three different types of indications of misalignments. A plug will not enter a hole, the plane of maximum misalignment is related to clock positions, and the angle of misalignment is related to the differences between min and max dial indicator readings. The mechanic is left to his own devices to determine the interaction of these three signals of the misalignment. Not surprisingly, he usually shims the engine by the long process of trial and error.

The problem of driveshaft alignment in helicopters was found to be significant by Kaman investigators as reported in USAAMRDL TR 75-7[3]. A general case solution for future design was outlined. Independent of the alignment problem investigations, the U.S. Army Aviation Systems Command (AVSCOM), identified the UH-1 driveshaft as a candidate for improvement, in order to reduce maintenance and to provide a longer service life. A driveshaft using KAflex couplings (a Kaman product) was selected for evaluation as a candidate replacement. The alignment of both the KAflex driveshaft and the standard Bell driveshaft were precisely measured during both ground and flight test of the baseline (Bell) driveshaft and the test (KAflex) driveshaft.

An opportunity thus existed for a real-world proof-of-concept test of a driveshaft alignment indicator. Equipment and procedures at hand included the bailed UH-1 and a driveshaft alignment measurement system, already tested and operational, to be used as a baseline monitoring system. The existing measurement system included telemetry of data to ground by pilot command, followed by computer printout of the driveshaft alignment. Driveshaft alignment had already been measured precisely throughout the UH-1 flight envelope.

This report describes work done to evaluate an in-flight driveshaft indicator that is suitable for use on both UH-1 and AH-1 aircraft, a survey to determine the driveshaft alignment now existing on Army helicopters, and an improved driveshaft alignment procedure including a simplified shimming technique.

---

3. Cook, T. N., Starses, F. E., Haire, G. W., ARMY AIRCRAFT SUBSYSTEM AND COMPONENT INSTALLATION DESIGN INVESTIGATION, Kaman Aerospace Corporation: USAAMRDL Technical Report 75-7, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, February 1975, AD A007245.

DRIVESHAFT ALIGNMENT INDICATOR DESIGN DESCRIPTION

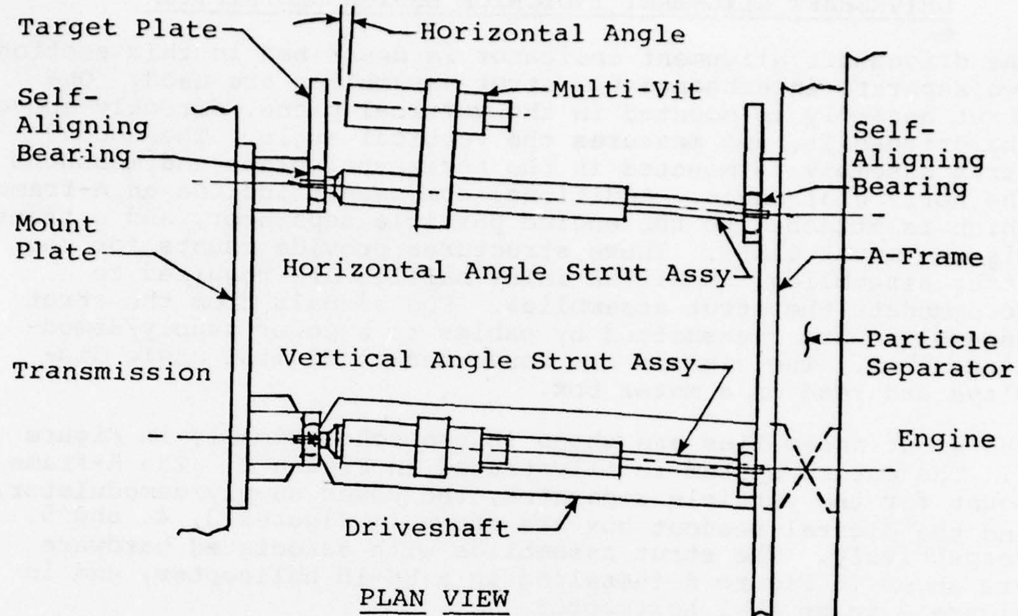
The driveshaft alignment indicator is described in this section. Two separate interchangeable strut assemblies are used. One strut assembly is mounted in the vertical plane, directly above the driveshaft, and measures the vertical angle. The second strut assembly is mounted in the horizontal plane and measures the horizontal angle. Additional components include an A-frame, which is attached to the engine particle separator, and a transmission mount plate. These structures provide mounts for the strut assemblies. Modified inlet baffles are required to accommodate the strut assemblies. The signals from the strut assemblies are transmitted by cables to a power supply/demodulator box. The signals are converted to digital angle displays and read on a meter box.

The strut assemblies are shown in use schematically in Figure 1. The entire system is illustrated in Figure 2. The A-frame mount for the particle separator, the power supply/demodulator, and the digital readout box are shown in Figures 3, 4, and 5, respectively. The strut assemblies with associated hardware are shown in Figure 6 installed in a UH-1H helicopter, and in Figure 7 in an AH-1 helicopter.

Each strut assembly consists of a telescoping shaft to which is mounted at Multi-Vit sensor. The Multi-Vit sensor is a noncontacting electronic micrometer which is extremely accurate.* The shaft is freely extensible or compressible to accommodate change of length. The strut engages self-aligning bearings at each end. The bearings are mounted in a target plate whose location is sensed by the Multi-Vit. The target plate also contains an alignment hole which receives an aligning pin attached to the strut assemblies. The alignment pin/hole arrangement keeps the Multi-Vit aimed at the target plate.

The strut assemblies form a trapezoid with the driveshaft, as can be seen in Figure 1. A coupling angle change causes a slightly amplified angle change between the strut assembly and the target plate. The angle between the strut assembly and the target plate is measured by the Multi-Vit in terms of distance from the Multi-Vit to the target plate. The distance measurement is converted to an angle, corrected for the aforementioned amplification, and displayed in degrees (x.xx) on the panel meter on the digital readout box. There is no mixing of the signals from the two strut assemblies. The angle measurements are completely independent.

* Product of Kaman Sciences Corporation, 1500 Garden of the Gods Road, Colorado Springs, Colorado, 80907.



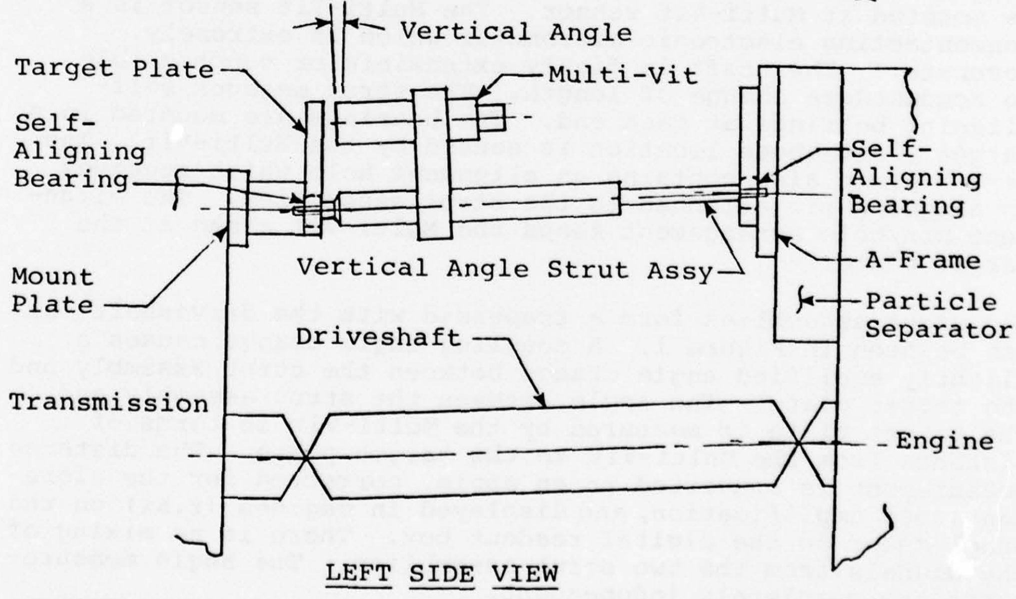


Figure 1. Strut Installation - Schematic.

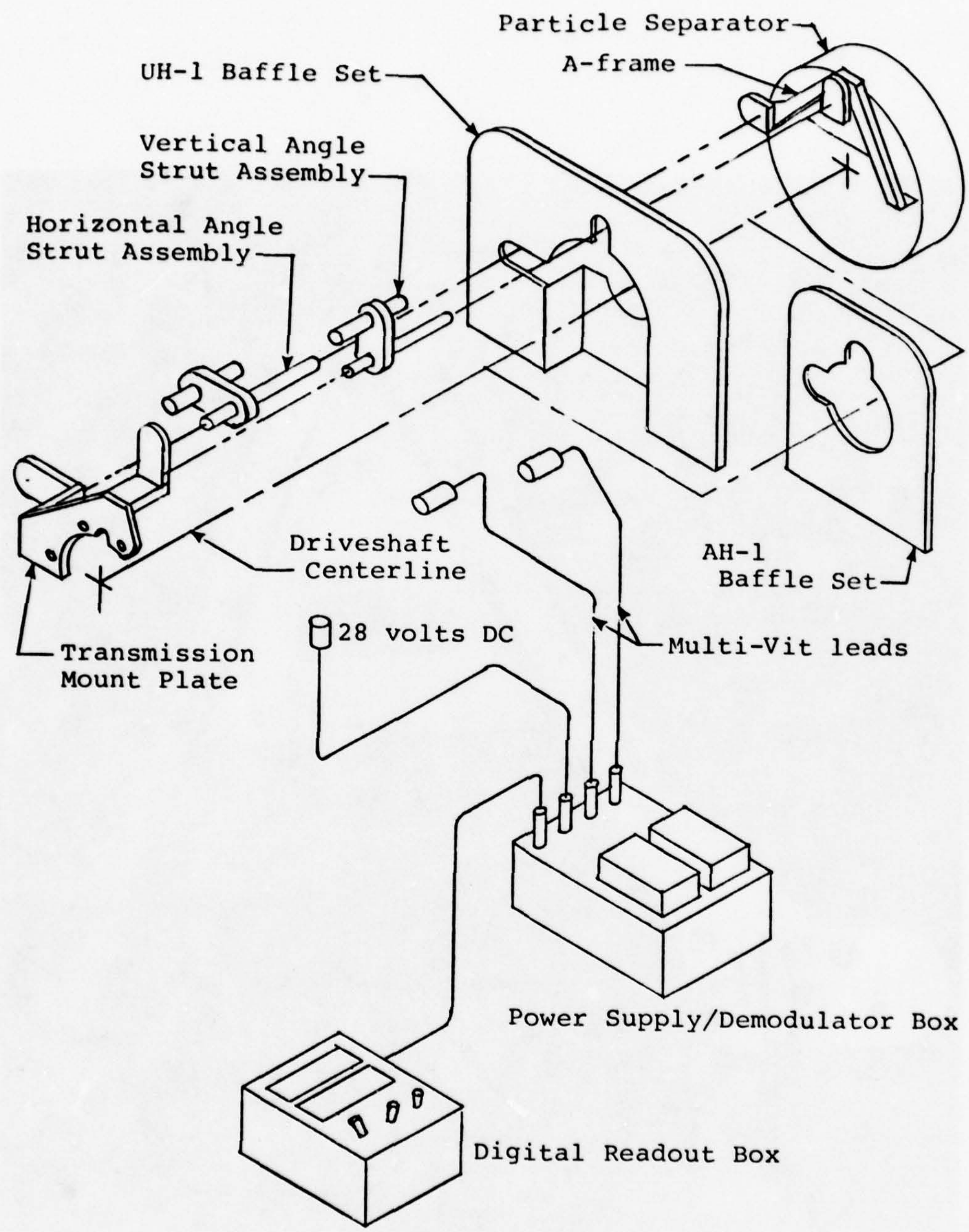


Figure 2. Driveshaft Alignment Indicator Installation - Schematic.

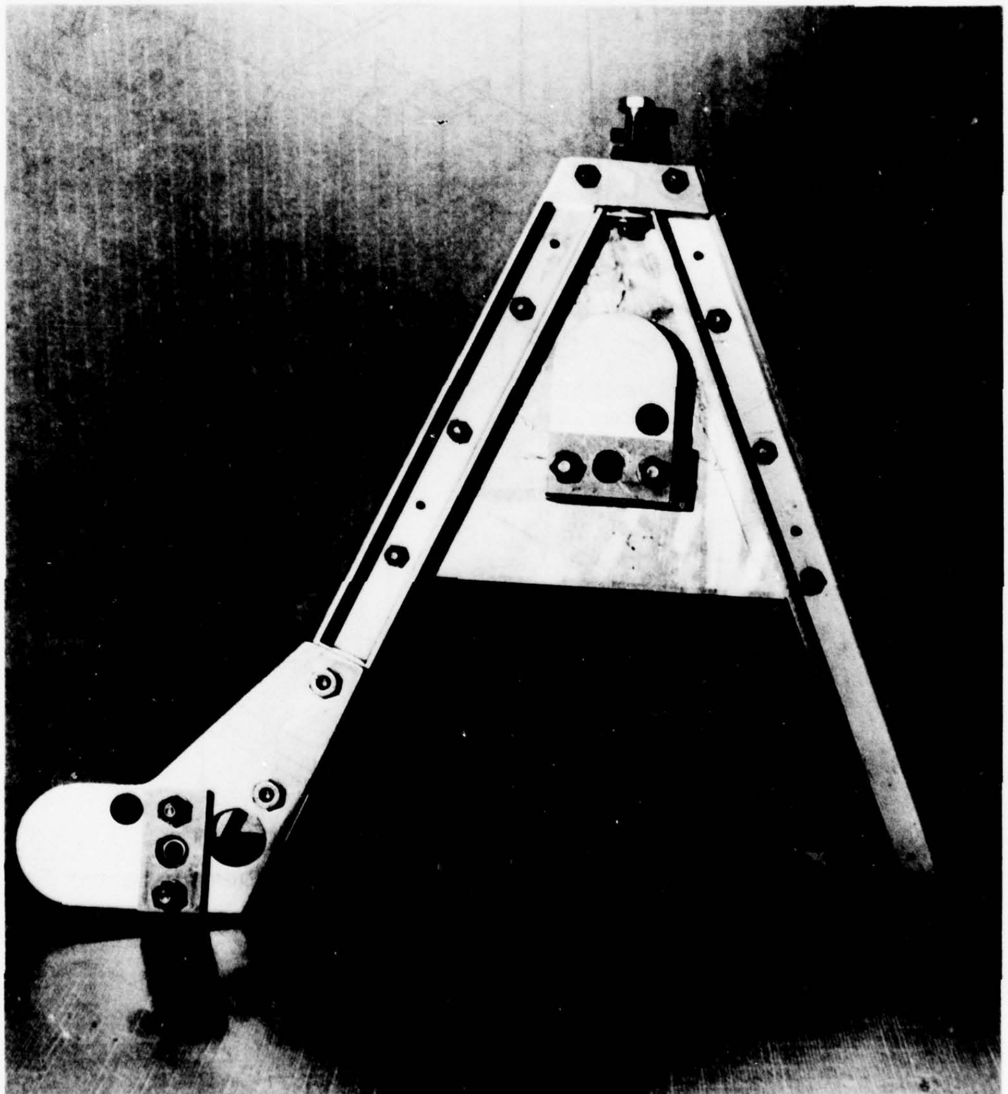


Figure 3. A-Frame Mount.

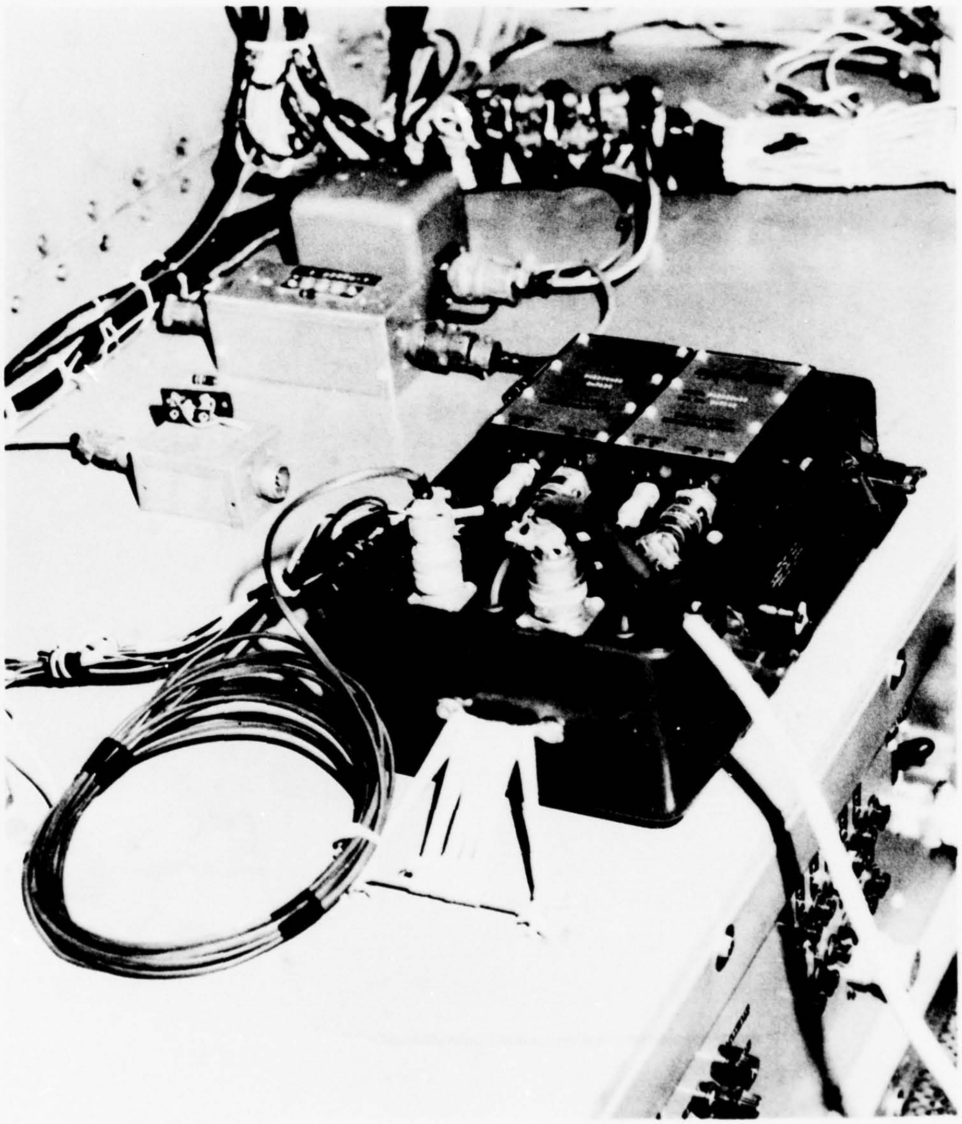


Figure 4. Power Supply/Demodulator Box.

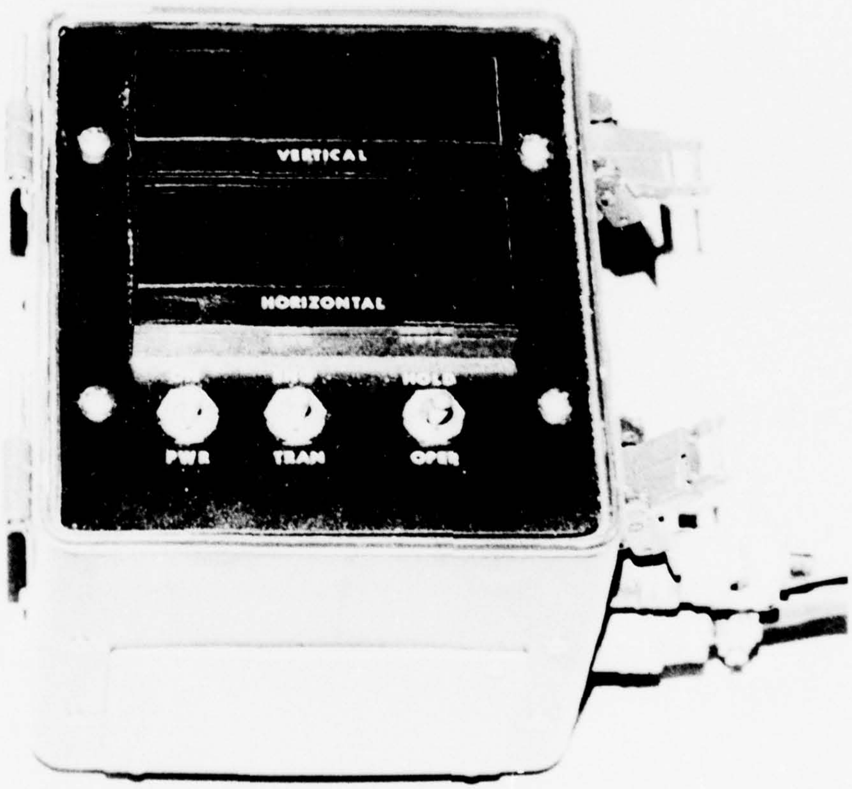


Figure 5. Digital Readout Box.

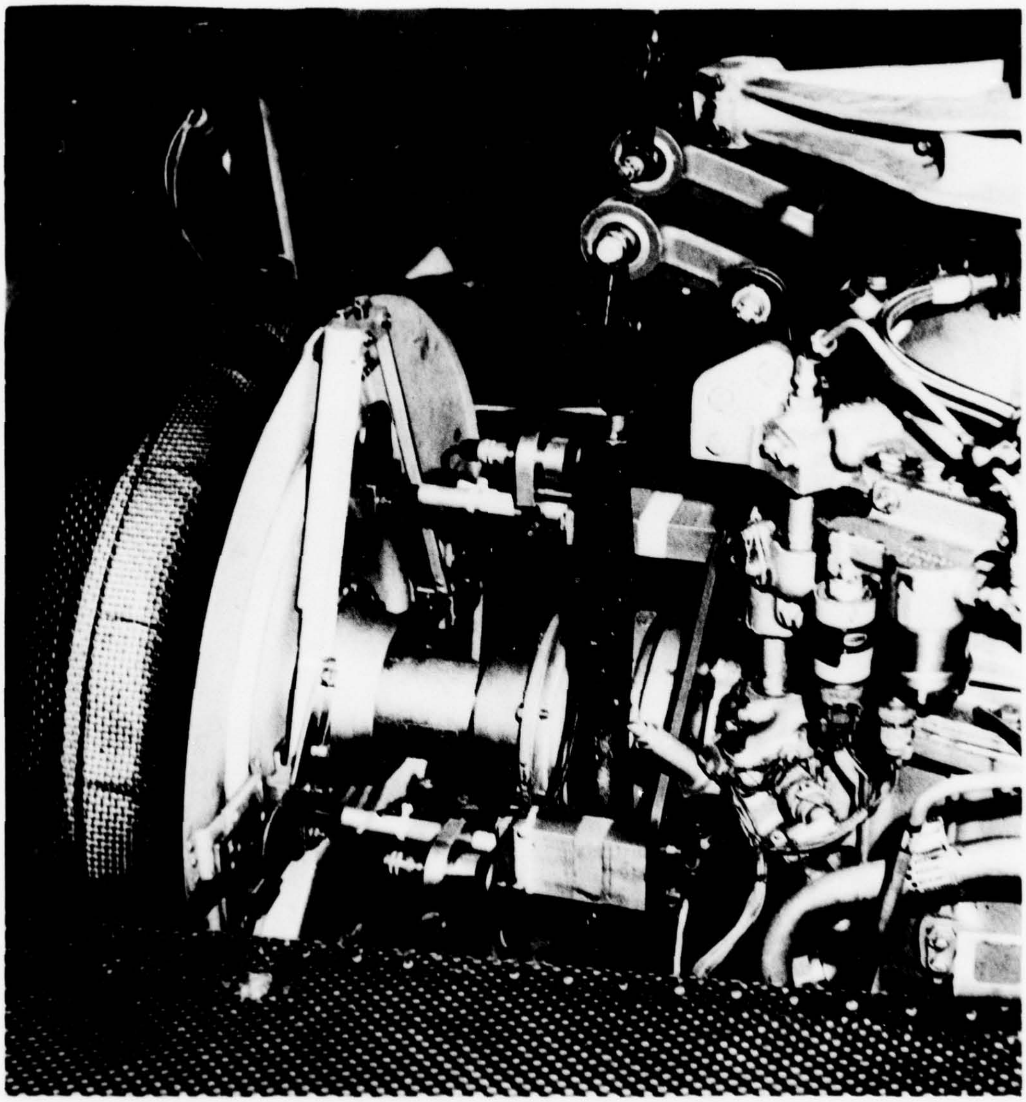


Figure 6. Strut Assemblies Installed in a UH-1H Helicopter. Upper Half of Induction Baffle is Omitted for Clarity.

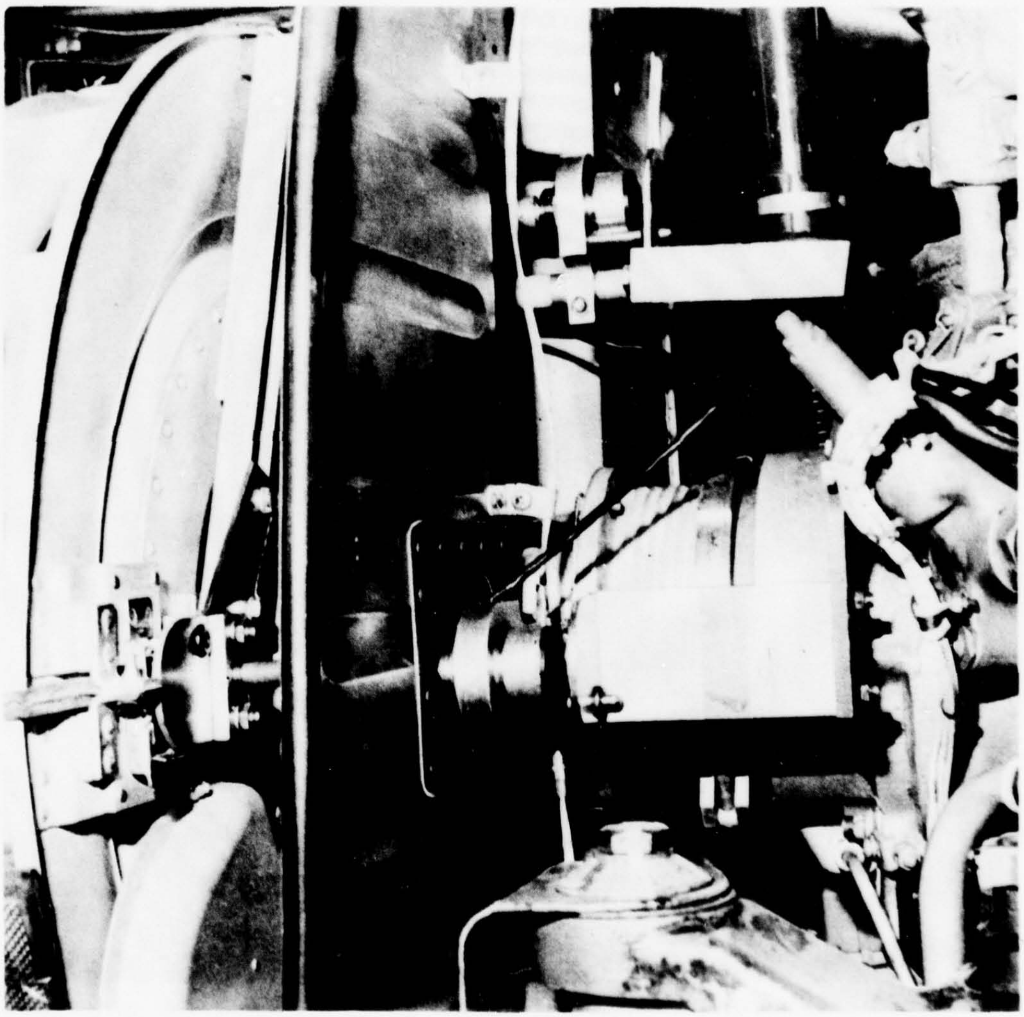


Figure 7. Strut Assemblies Installed in an AH-1 Helicopter.

The angle measurements reproduce the arrangement used for vertical angle measurements in the first contract. The original vertical angle measurement was found to be very precise. It was shown to be not affected by changes in the horizontal angle or by relative rotation of the engine with respect to the transmission. It was not affected by the radial distance from the driveshaft to the link assembly.

Driveshaft change of length was found to be very slight and of no practical significance. It need not be measured. Also, the difference in length between the standard driveshaft (8.68 inches) and the KAflex driveshaft (7.56 inches) did not have a significant effect on measured misalignment angles. Plots of the angle measurements made with each shaft can be superimposed with no discernible difference.

The strut assemblies are interchangeable. This has the advantage of allowing both angles to be measured, although only one at a time, in the event that one system malfunctions. Also, the use of two identical strut assemblies will reduce the cost of procurement and in-service cost.

The strut assemblies can be reversed to read the alignment angles of the engine-end coupling. A switch on the digital readout box is used to select the appropriate correction circuits for the transmission-end coupling or the engine-end coupling. Measurement of the misalignment of the engine-end coupling is not felt to be as important as the measurement of transmission-end coupling misalignment. Transmission-end coupling misalignment is larger than engine-end coupling misalignment because the transmission is isolation-mounted while the engine is not. As a result, the transmission rotates about the rotor axis in response to a torque change, causing the larger horizontal angle to occur at the transmission-end coupling. Also, when the transmission rocks about a transverse axis in response to fore-and-aft cyclic pitch, the larger vertical angle occurs at the transmission-end coupling. Historically, the transmission-end coupling has shown more wear than the engine-end coupling, which also indicates larger misalignment. However, the option of actually measuring engine-end coupling misalignment could be useful in a troubleshooting situation.

The driveshaft alignment indicator will fit both the UH-1 and the AH-1 helicopters. It has been observed that the AH-1 mission causes more large-misalignment events than the UH-1 mission. Thus, dynamic alignment measurement is important to the AH-1. The driveshafts are the same, as are the input quill geometry and the particle separator geometry. The intake baffles and the control systems are different.

The digital readout box contains adjustments for zero and slope. Zero misalignment can be set physically with a ceramic spacer between the Multi-Vit and the target plate. Then the zero-set adjustment on the digital readout box is turned until the digital panel meter reads 0.00 degrees. A similar adjustment for slope changes the reported angle versus the apparent angle. However, the actual driveshaft angle has to be measured, such as with a dial indicator, to verify the proper slope. Slope change is needed to accommodate the difference between the angle seen by the strut assembly and the angle experienced by the driveshaft coupling.

Important design characteristics are listed below:

1. Usable on UH-1 and AH-1 helicopters.
2. Usable with the standard gear coupling or the KAflex coupling.
3. Interchangeable strut assemblies.
4. Reversible strut assemblies.
5. Usable without driveshaft removal.

PROTOTYPE VERIFICATION

Verification of the ability of the driveshaft alignment indicator (DSAI) to measure driveshaft alignment is reported in this section. This verification was accomplished by comparing the alignment readings of the prototype DSAI with a baseline monitoring system. The baseline monitoring system was developed for flight testing of a UH-1 driveshaft using KAflex couplings. The alignment of both the standard Bell driveshaft and the KAflex driveshaft were precisely measured during both ground and flight test. The measurement system included telemetry of data to ground by pilot command, followed by computer printout of the driveshaft alignment. Driveshaft alignment was measured throughout the UH-1 envelope. The driveshaft was aligned per TM55-1520-210-20 as described in Appendix A.

The principle of operation of the baseline monitoring system is illustrated in Figure 8. Three Multi-Vits are mounted on the transmission at 120° intervals on a circle of 10.2 inches diameter. A steel disc is attached to the center shaft of the standard driveshaft assembly. At zero misalignment, the Multi-Vits are equally distant from the disc. The vertical, horizontal, and resultant total alignment angle of the transmission-end coupling, as well as change of length, can be calculated by geometric relationships. The angles calculated from Multi-Vit signals were checked staticallly by finding the distance from the Multi-Vits to the disc with a telescoping gage and measuring the telescoping gage with a micrometer. The angles were independently calculated using the micrometer measurements. They confirmed the angles calculated using the Multi-Vit sensors, thus providing angle measurements based on certified standards and traceable to the National Bureau of Standards.

Verification of the DSAI began with static testing. The driveshaft was aligned per Bell Helicopter Textron Service Bulletin No. 205-76-9[4] as described in Appendix B. The transmission-end coupling angle was measured simultaneously by using the telescoping gage with micrometer technique, by the baseline Multi-Vit system, and by the DSAI. All three systems concurred. The helicopter was then loaded to 8600 lbs gross weight and suspended by an overhead hoist attached to the rotor hub. Alignment angle measurements were taken using all three systems, while the helicopter was suspended, at 8600 lbs gross weight, aft C.G. (Station 138). The process was repeated for forward C.G. (Station 133).

---

4. ENGINE TO TRANSMISSION DRIVESHAFT ALIGNMENT Service Bulletin No. 205-76-9, Bell Helicopter Textron, Forth Worth, Texas, 9 September 1976.

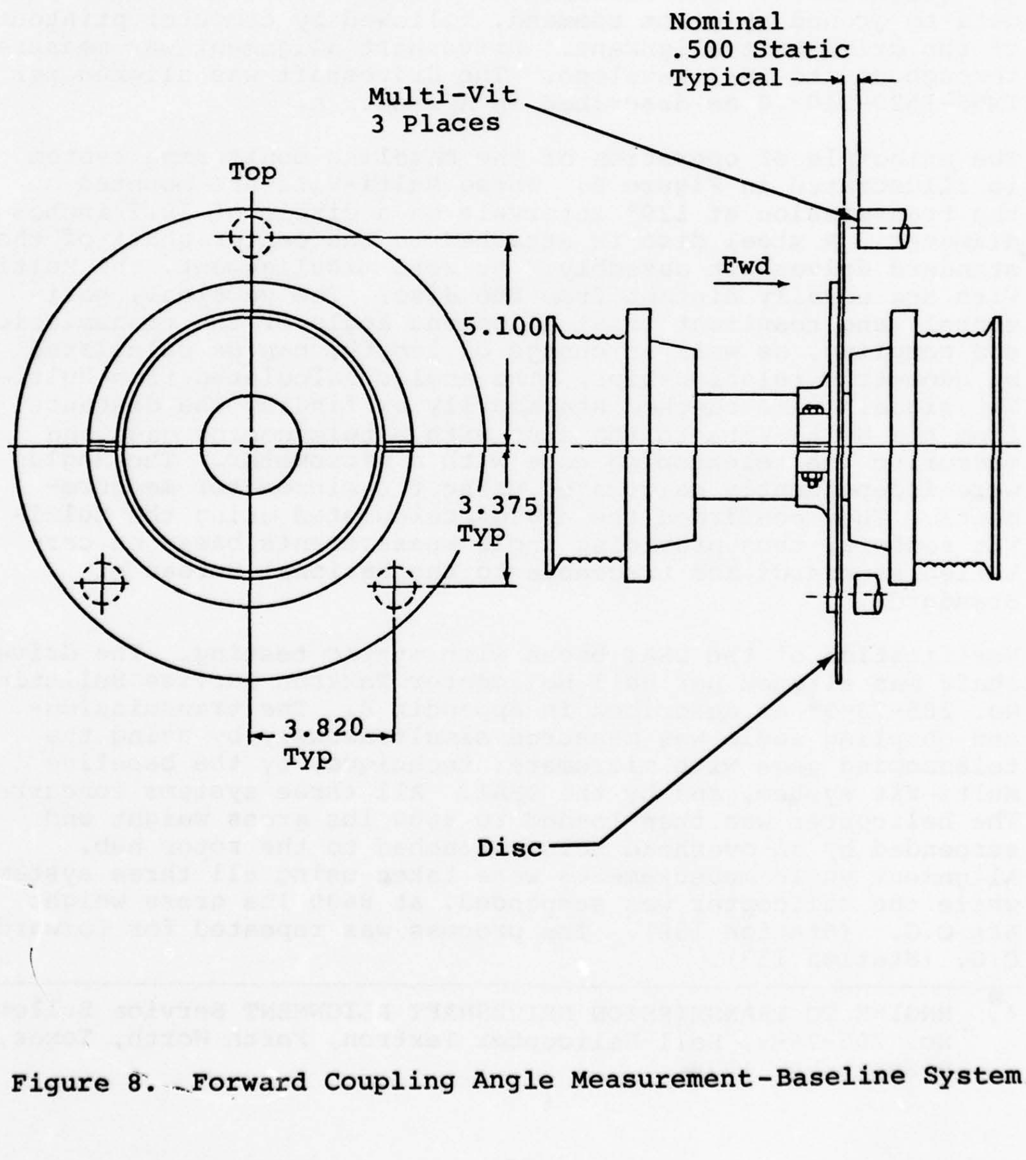


Figure 8. Forward Coupling Angle Measurement-Baseline System.

The DSAI was then flight tested. The DSAI features a hold switch that takes an average reading over a 2-second interval. The pilot held conditions for a data point for several seconds and then depressed a telemetry switch. The angle measurements of both the DSAI and the baseline monitoring system were simultaneously telemetered to ground and recorded on a computer printout. Measurements were taken throughout the UH-1 flight envelope for two conditions, 8600 lbs gross weight with max aft C.G. and 8600 lbs gross weight with max forward C.G. The results are given in Figures 9 through 16. Also included in Figures 9 through 12 are the alignments measured by the baseline monitoring system for alignment per TM55-1520-210-20 with 8600 lbs gross weight, max forward C.G. A positive vertical angle exists when the transmission-end coupling is above the engine-end coupling. A positive horizontal angle exists when the transmission-end coupling is to the right of the engine-end coupling. Positive vertical angle measurements at max aft C.G. show the DSAI measurements to be consistently smaller than the baseline monitoring system. The discrepancy was cause for concern. However, the consistent low readings had not occurred previously. Also, they did not occur during the testing required to develop shim curves, as reported in the next section. The shim curve tests are reported in Table 1 and illustrated in Figures 18 through 23. Subsequently it was learned that the DSAI develops a drift of 0.2 degree per hour, after the power has been on for an hour, thus explaining the variations in accuracy. Consequently, all testing was done with as short a power-on period as possible. In any event, the trend indicates that the field survey measurements would tend to minimize misalignment, not exaggerate misalignment. Repeating the flight test was judged not worth the cost.

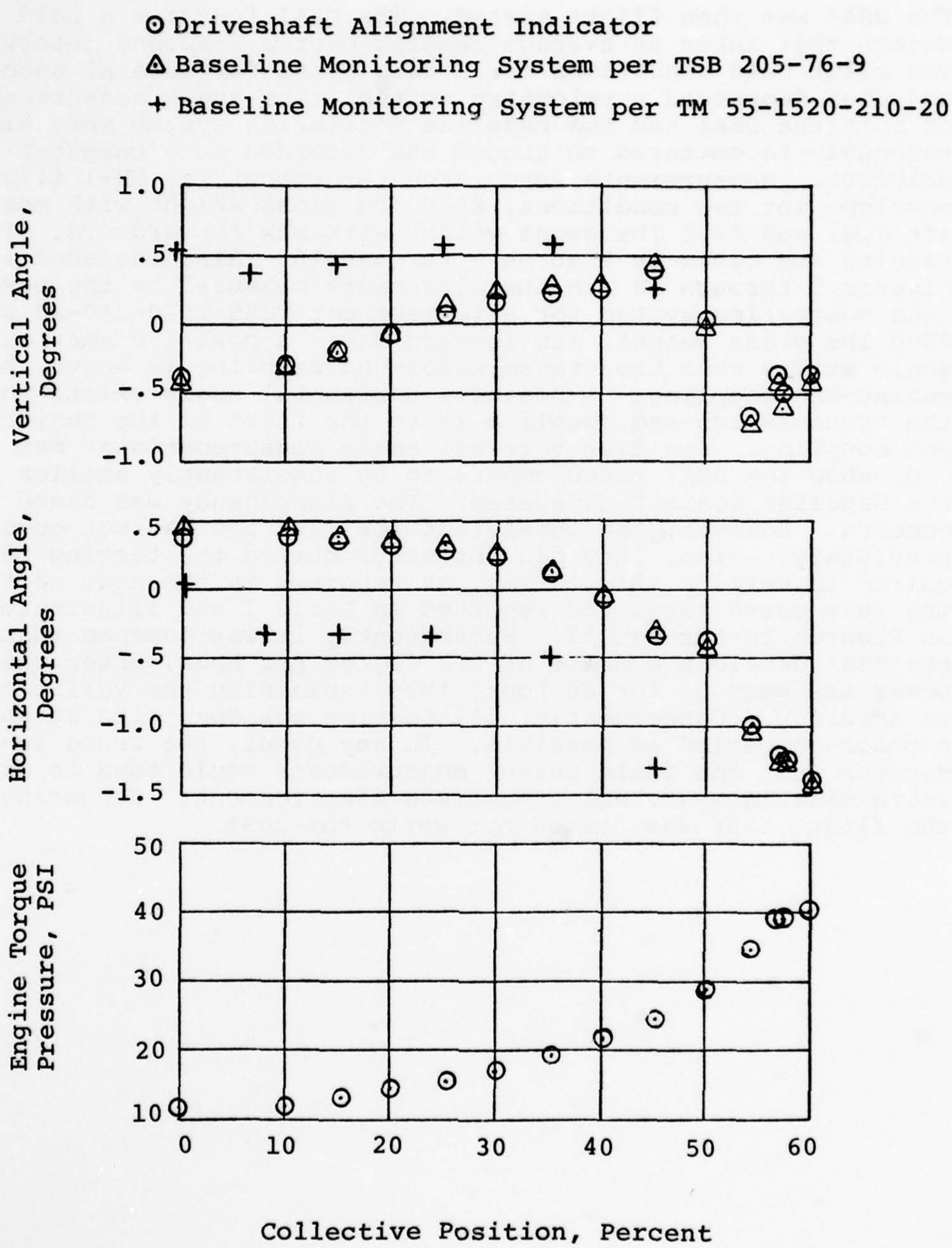


Figure 9. Ground and Hover Alignments, Forward C.G. (Station 133), 8600 Lbs G.W.

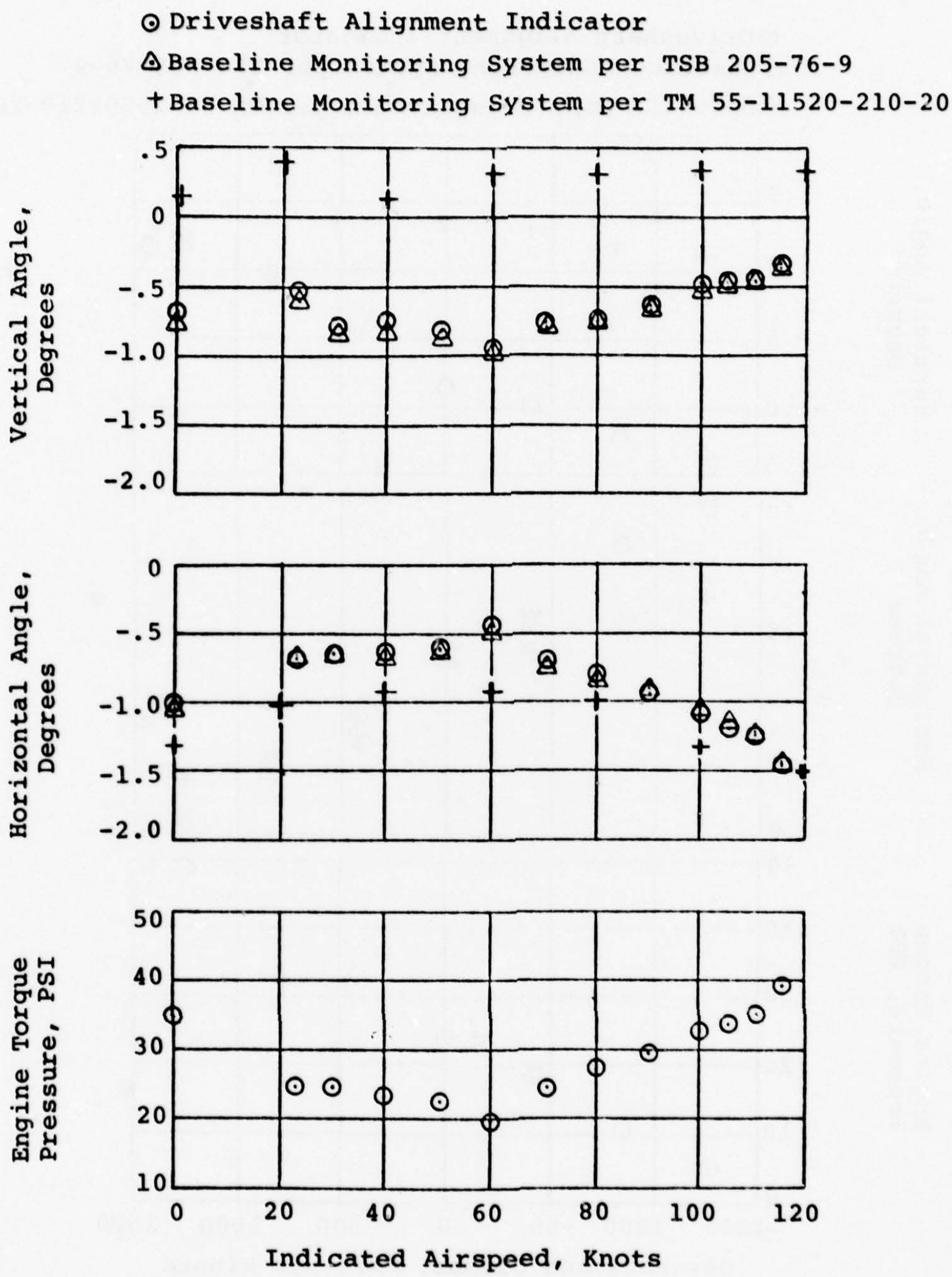


Figure 10. Forward Flight Alignments, Forward C.G. (Station 133), 8600 Lbs G.W.

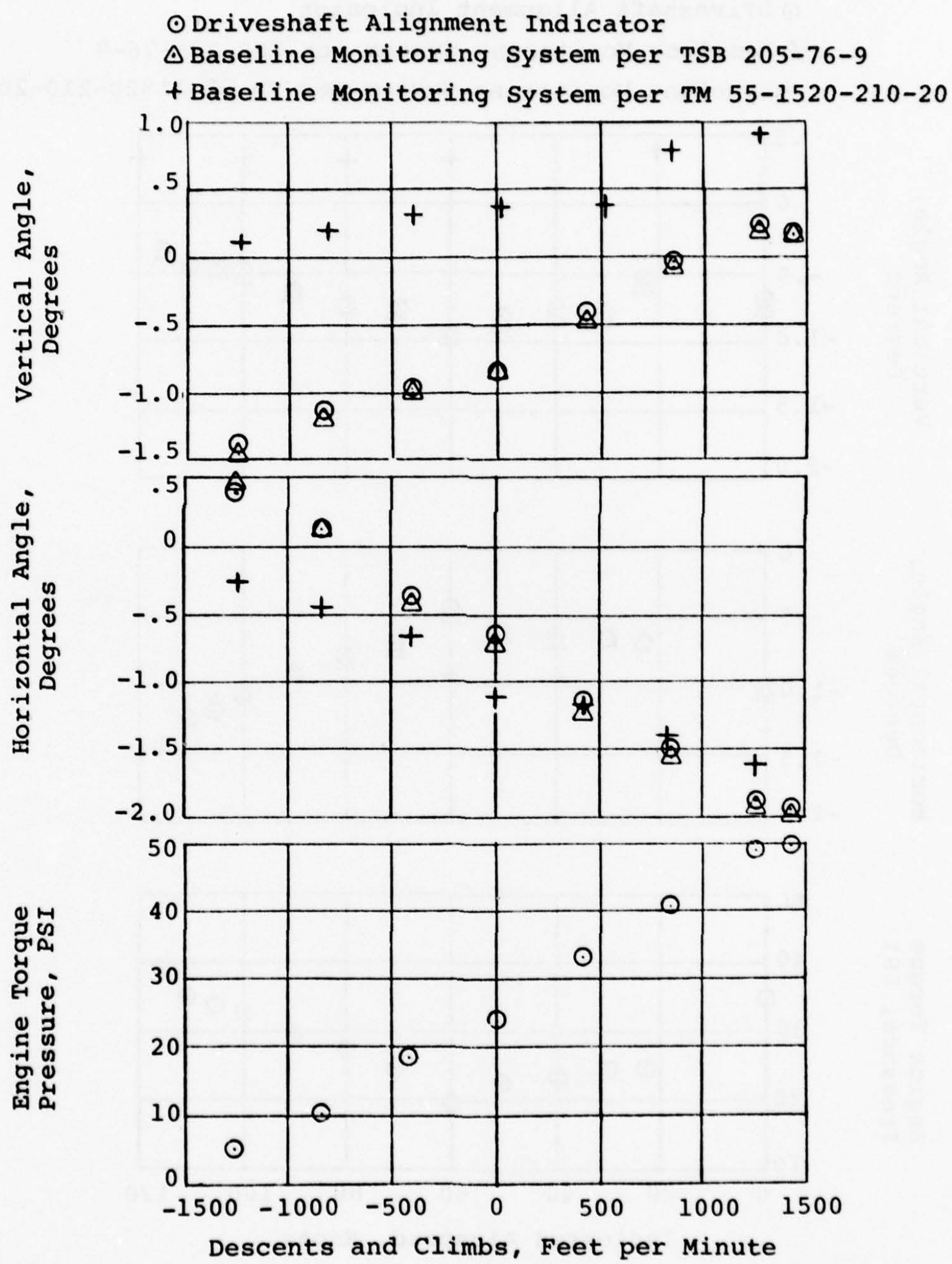


Figure 11. Descent and Climb Alignments, Forward C.G. (Station 133), 8600 Lbs G.W.

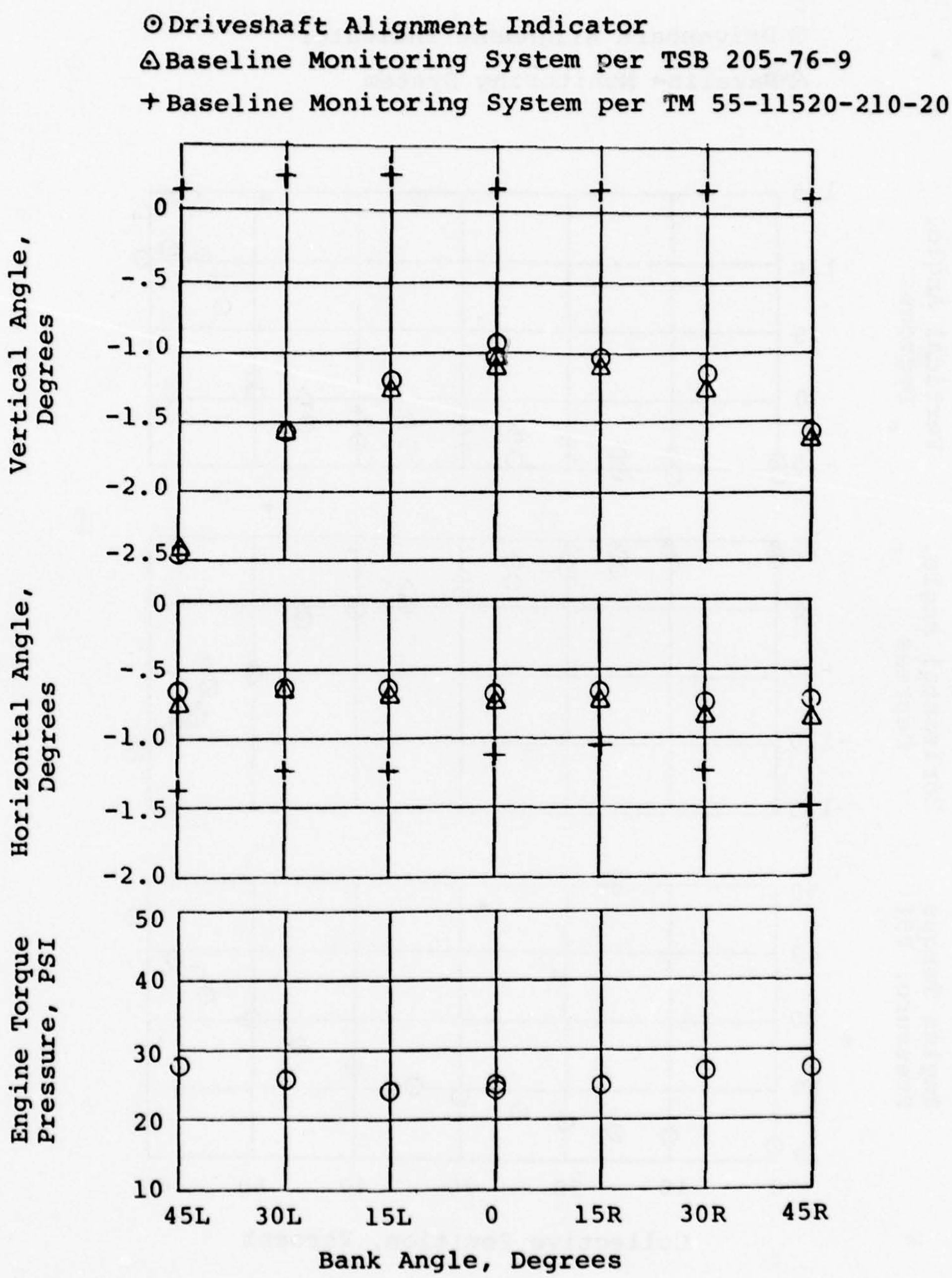


Figure 12. Bank Angle Alignments, Forward C.G. (Station 133), 8600 Lbs G.W.

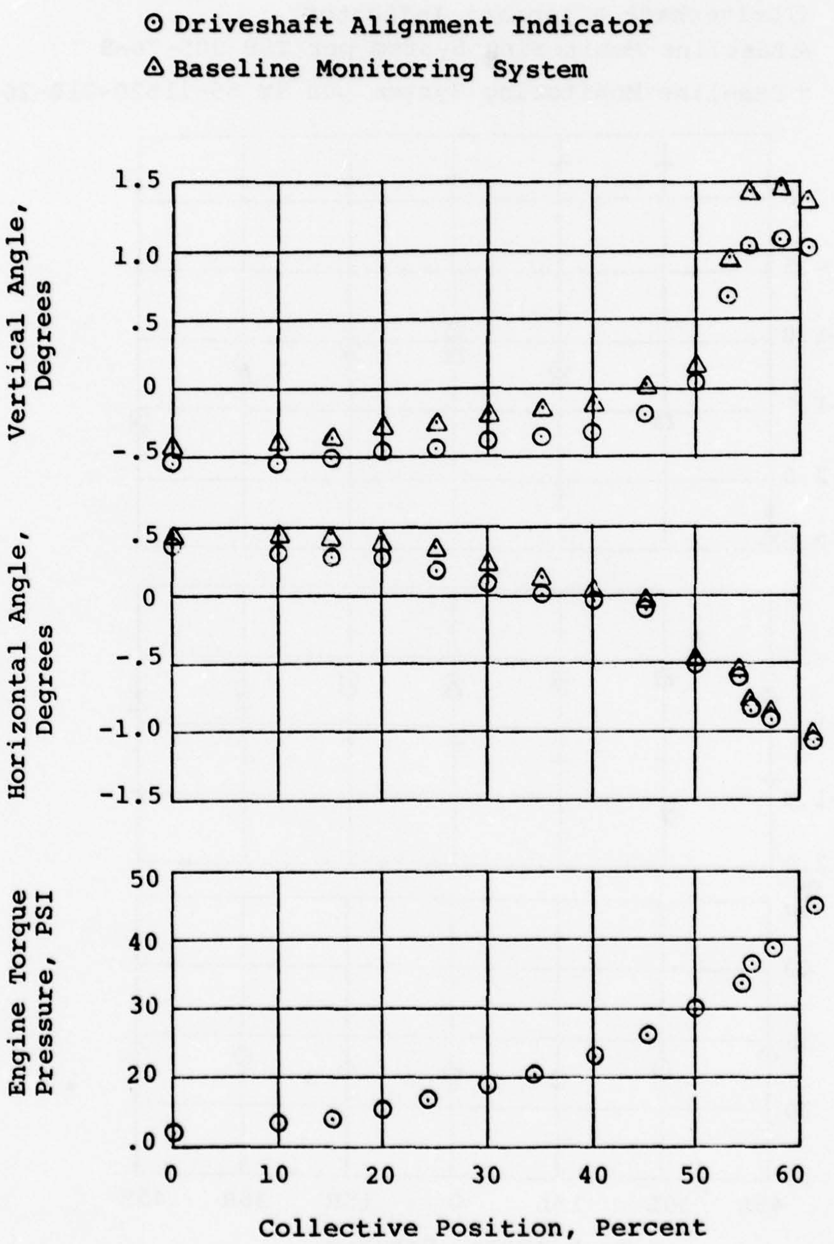


Figure 13. Ground and Hover Alignments, Aft C.G. (Station 138), 8600 Lbs G.W.

Figure 4. Power Supply/Demodulator Box.

17

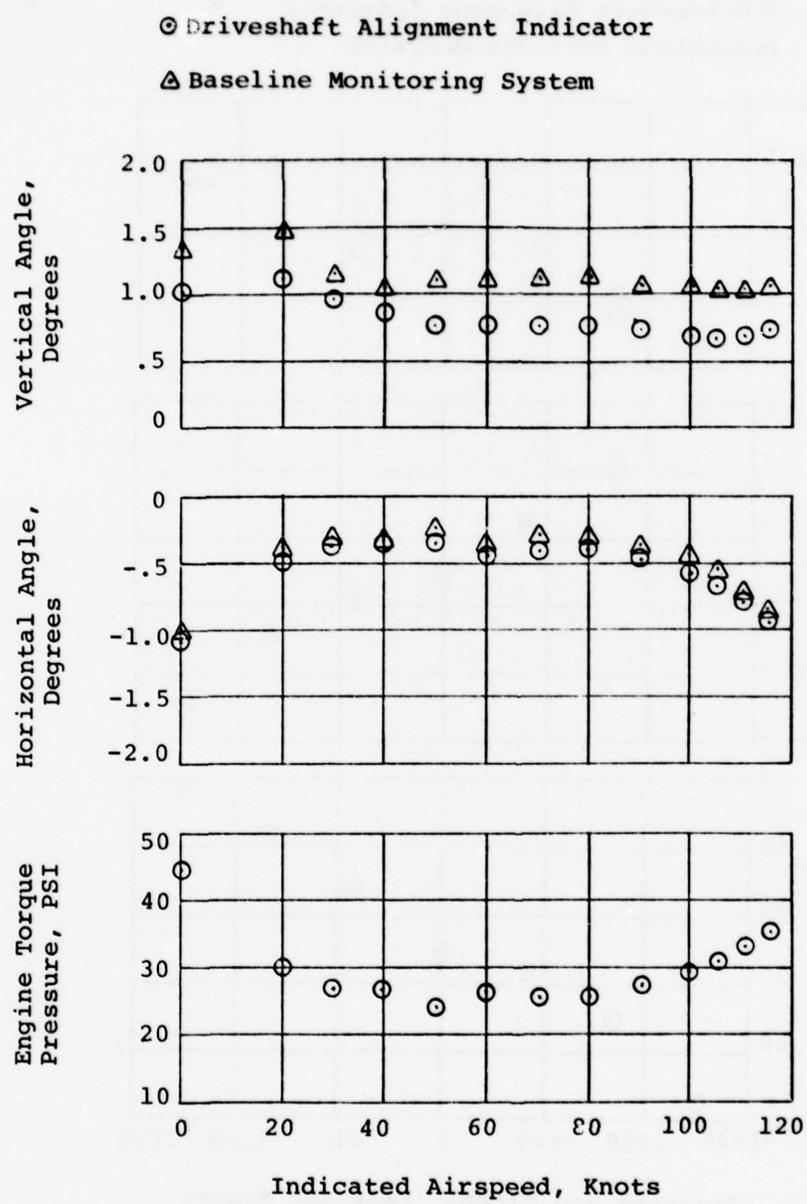


Figure 14. Forward Flight Alignments, Aft C.G. (Station 138), 8600 Lbs G.W.

Figure 5. Digital Readout Box.

18

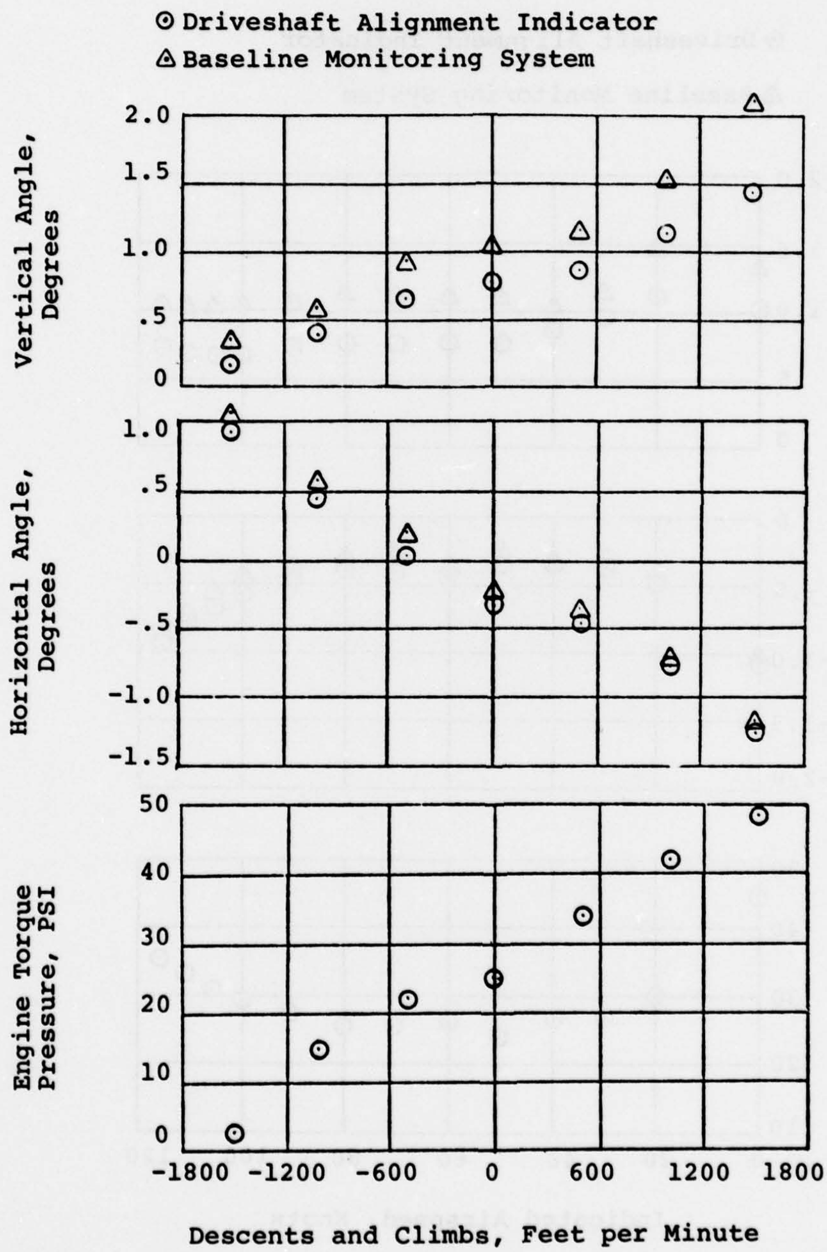


Figure 15. Descent and Climb Alignments, Aft C.G. (Station 138), 8600 Lbs G.W.

Helicopter. Upper Half of Induction Baffle is Omitted for Clarity.

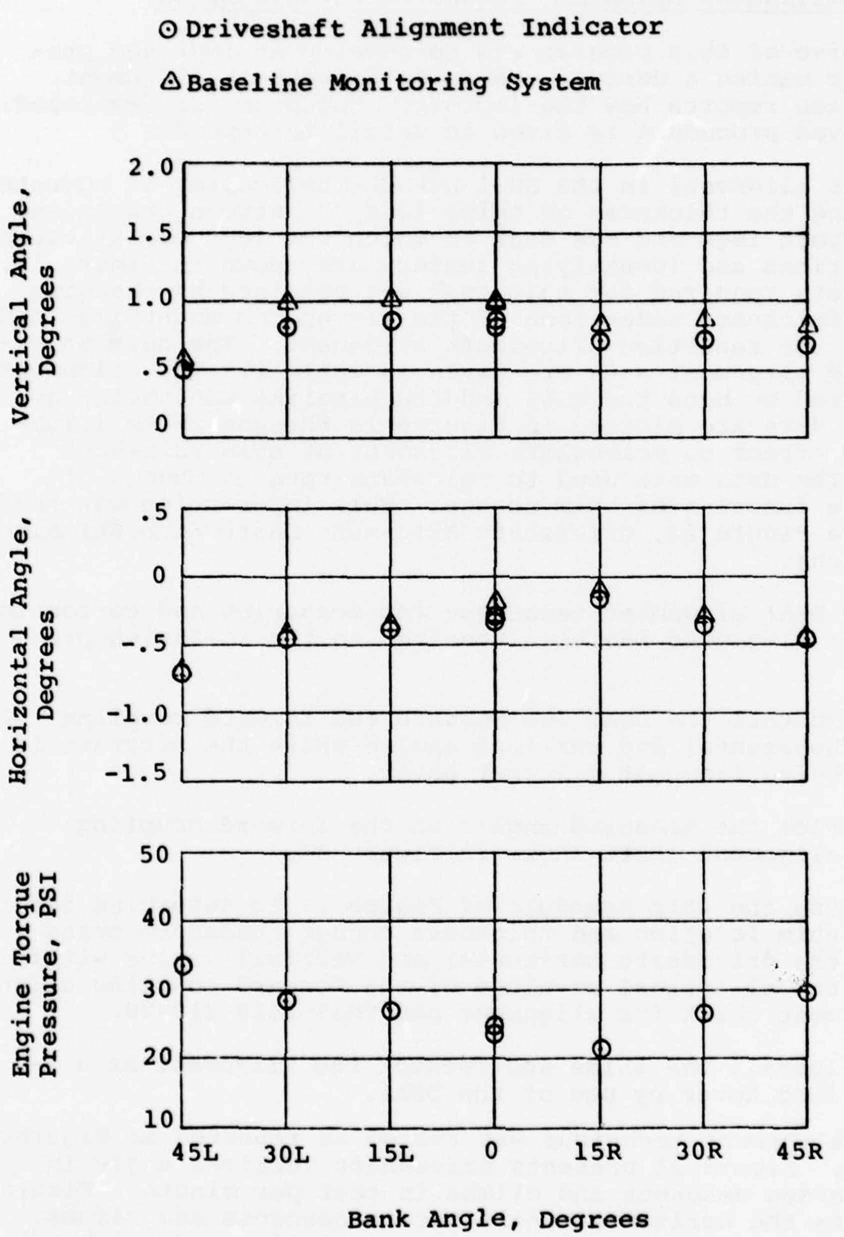


Figure 16. Bank Angle Alignments, Aft C.G. (Station 138), 8600 Lbs G.W.

Figure 7. Strut Assemblies Installed in an AH-1 Helicopter.

20

DRIVESHAFT ALIGNMENT PROCEDURE INVESTIGATION

An objective of this program was to develop an improved procedure for making a desired change in driveshaft alignment. This section reports how the improved procedure was developed. The improved procedure is given in detail in Appendix C.

Driveshaft alignment in the UH-1 and AH-1 helicopter is adjusted by changing the thickness of shims located between the engine mount support legs and the deck to which the legs are attached. Shim locations and identifying letters are shown in Figure 17. Initial data required for this task was obtained by changing the shim thickness under each of the six engine mount legs and measuring the resulting driveshaft alignment. The shim thicknesses and alignment data are given in Table 1. The alignment was measured by both the DSAI and the baseline monitoring system. The data are plotted in Figures 18 through 23 to illustrate the effect on driveshaft alignment of shim thickness change. The data were used to calculate rate of change of angle as a function of shim change. This information was used to prepare Figure 24, Driveshaft Alignment Chart With Shimming Instructions.

Thus, the DSAI alignment technique for measuring and correcting driveshaft alignment has been resolved to the following procedure:

1. Install the DSAI and measure the forward coupling horizontal and vertical angles while the aircraft is being flown at a 5-foot hover.

2. Plot the measured angles on the forward coupling alignment chart shown in Figure 24.

3. Use the shim schedule of Figure 24 to determine the shim location and thickness change needed to bring the driveshaft horizontal and vertical angles within the elliptical envelope of the forward coupling alignment chart for alignment per TM55-1520-210-20.

4. Install the shims and recheck the alignment at a 5-foot hover by use of the DSAI.

The DSAI alignment technique was tested as reported in Figures 25 and 26. Figure 25 presents driveshaft vertical angle in degrees versus descents and climbs in feet per minute. Figure 26 presents the horizontal angle versus descents and climbs. Data are presented for a gross weight of 8600 pounds with both a forward and an aft C.G. location. In addition, the driveshaft angles are shown for a predicted and observed alignment change. Comparison of the predicted and observed alignment change indicates that the technique is satisfactory.

take baffles and the control systems are different.

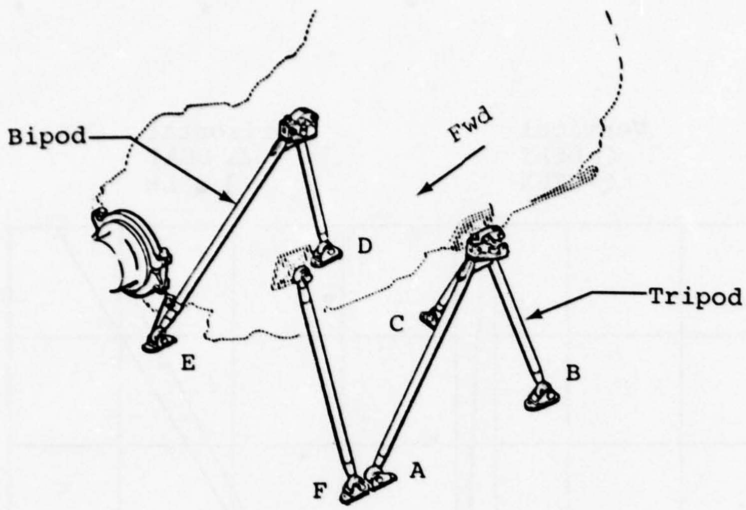


Figure 17. Shim Location and Identification.

TABLE 1. SHIM THICKNESS AND FORWARD COUPLING ALIGNMENT

SHIM LOCATION AND THICKNESS, INCHES						VERTICAL ANGLE, DEGREES		HORIZONTAL ANGLE, DEGREES	
A	B	C	D	E	F	DSAI	BSLN	DSAI	BSLN
0	.063	.250	.157	.062	.181	-1.12	-1.11	+0.69	+0.76
.300	"	"	"	"	"	-1.35	-1.25	+2.68	+2.95
0	"	"	"	"	"	-1.39	-1.11	+0.67	+0.81
"	.300	"	"	"	"	+1.75	+1.46	-3.58	-3.00
"	0	"	"	"	"	-2.18	-1.73	+1.73	+1.96
"	.063	"	"	"	"	-1.39	-1.10	+0.67	+0.80
"	"	.125	"	"	"	-1.03	-0.81	-0.50	-0.41
"	"	0	"	"	"	-0.54	-0.60	-1.47	-1.42
"	"	.250	.300	"	"	-1.59	-1.25	+1.58	+1.59
"	"	"	0	"	"	-0.32	-0.20	-1.75	-1.41
"	"	"	.157	.300	"	-0.76	-0.78	-1.42	-1.21
"	"	"	"	0	"	-1.06	-0.92	+0.98	+1.02
"	"	"	"	.062	.300	-3.33	-2.65	+0.69	+0.87
"	"	"	"	"	.150	-0.74	-0.66	+0.68	+0.77
"	"	"	"	"	0	+1.83	+1.49	+0.62	+0.76
"	"	"	"	"	.181	-1.11	-0.89	+0.34	+0.45

DSAI: Driveshaft Alignment Indicator
BSLN: Baseline Monitoring System

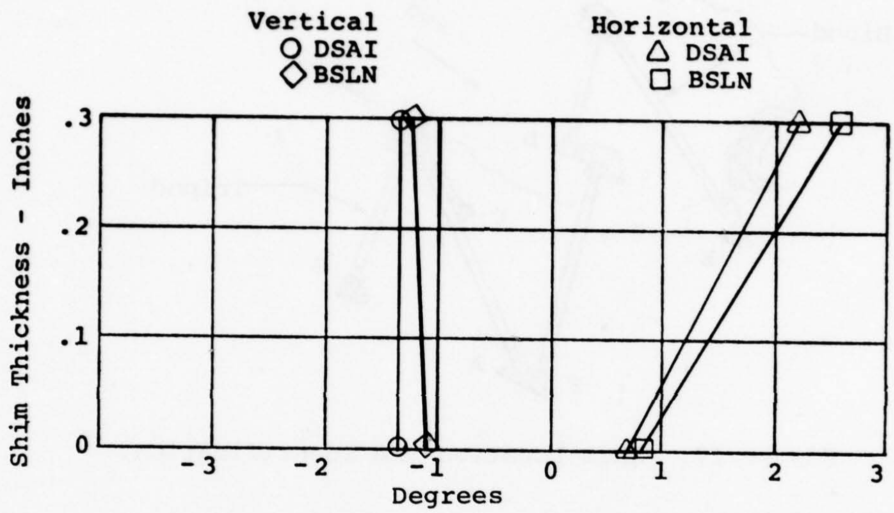


Figure 18. Leg "A" Shim Curve.

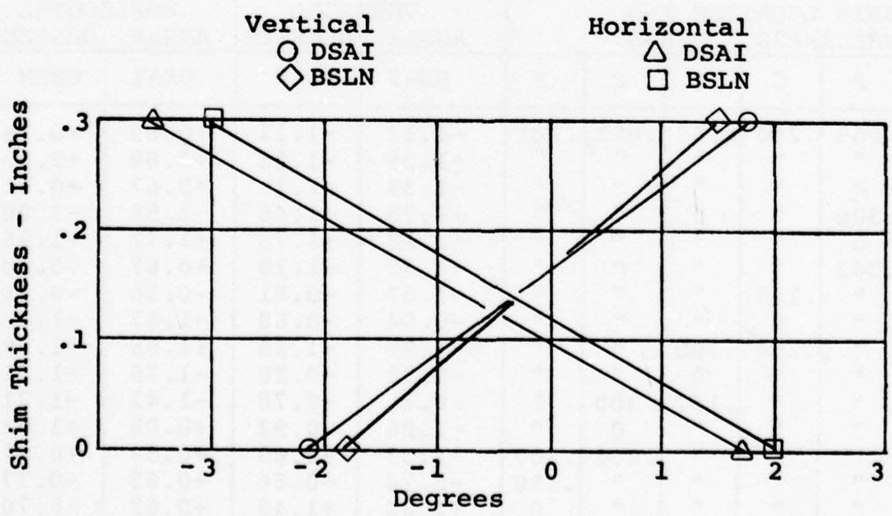


Figure 19. Leg "B" Shim Curve.

9 September 1976.

23

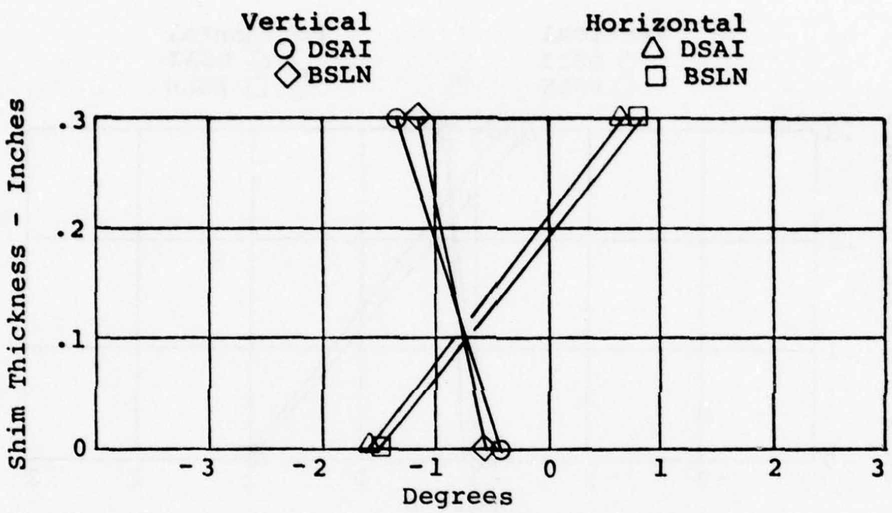


Figure 20. Leg "C" Shim Curve.

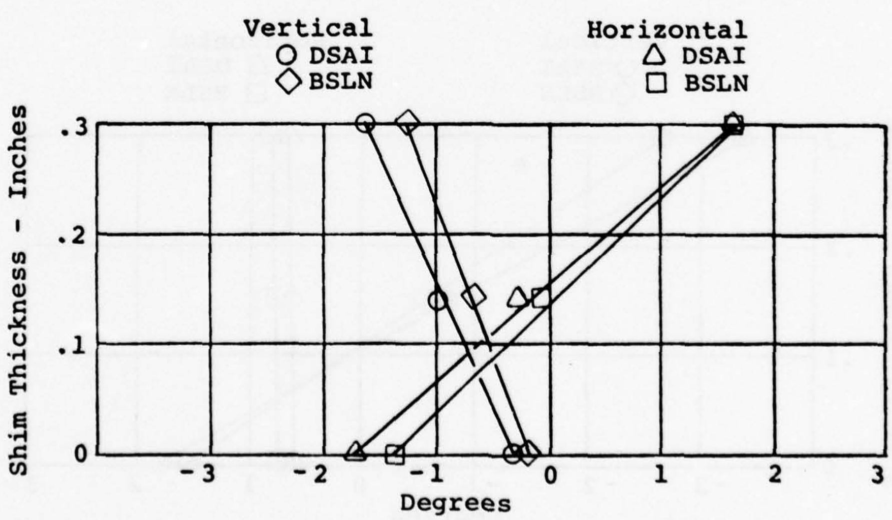


Figure 21. Leg "D" Shim Curve.

Figure 8. Forward Coupling Angle Measurement-Baseline System.

24

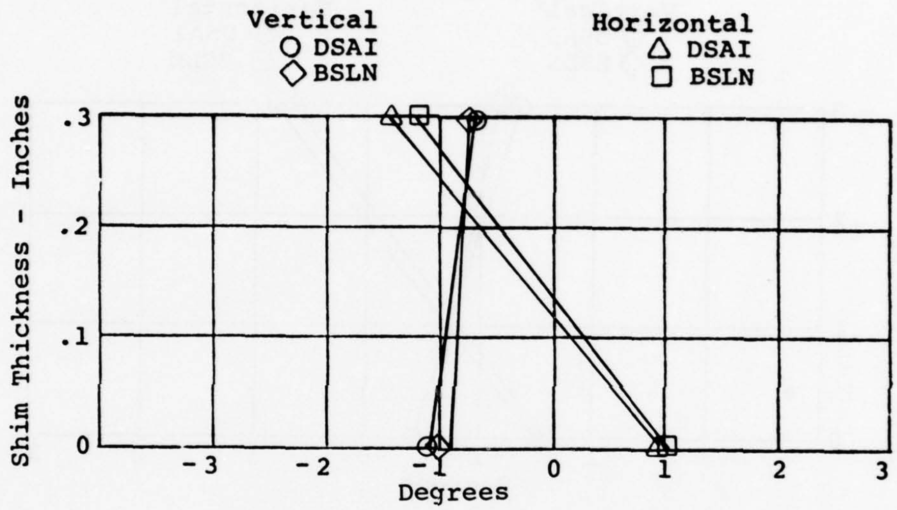


Figure 22. Leg "E" Shim Curve.

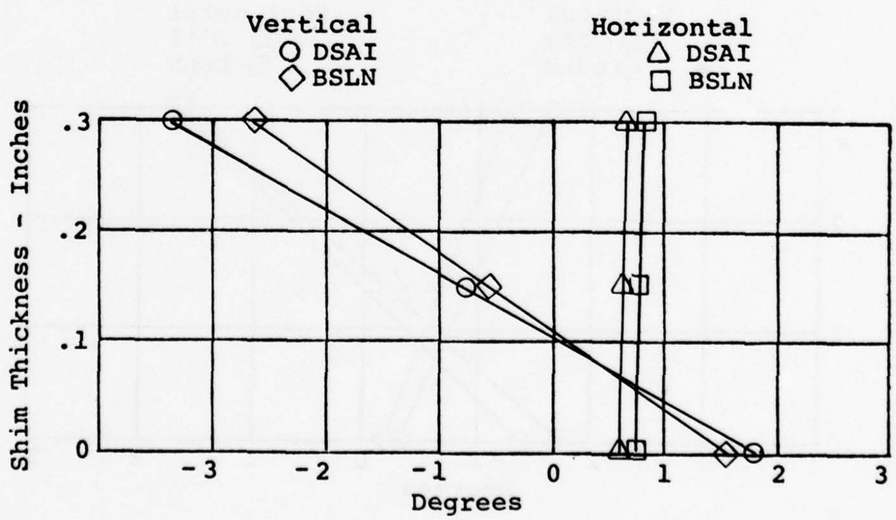
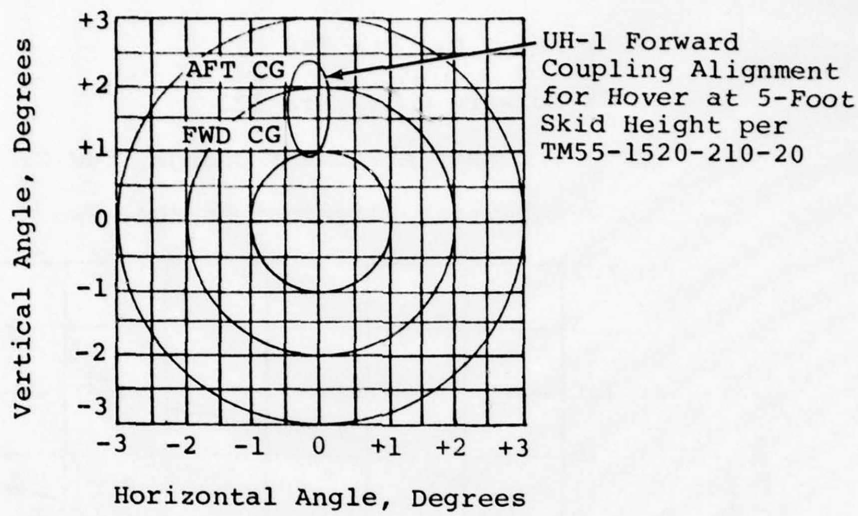


Figure 23. Leg "F" Shim Curve.



To move 1/2 degree to the left, remove .075" from Leg "A".
To move 1/2 degree to the right, add .075" to Leg "A".
To move 1/2 degree to the left, add .063" to Leg "E".
To move 1/2 degree to the right, remove .063" from Leg "E".
To move 1/2 degree up, remove .029" from Leg "F".
To move 1/2 degree down, add .029" to Leg "F".
To move 1/2 degree up and 1/2 degree right, add .038" to Leg "B".
To move 1/2 degree down and 1/2 degree left, remove .038" from Leg "B".
To move 1/2 degree left and 1/4 degree up, add .058" to Leg "C".
To move 1/2 degree right and 1/4 degree down, remove .058" from Leg "C".
To move 1/2 degree left and 1/4 degree down, remove .045" from Leg "D".
To move 1/2 degree right and 1/4 degree up, add .045" to Leg "D".

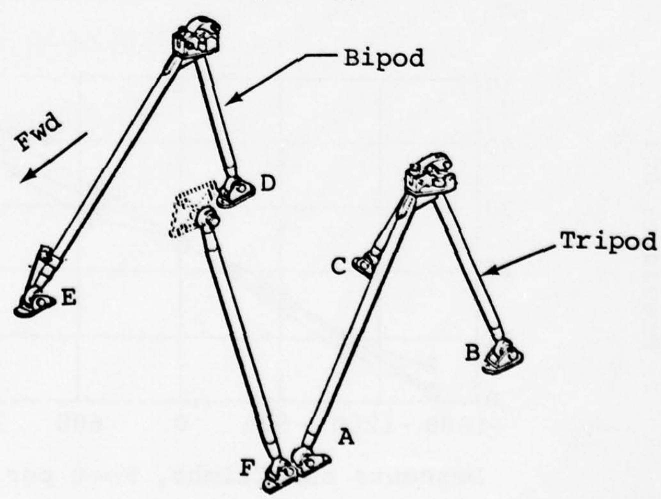


Figure 24. Driveshaft Alignment Chart with Shimming Instructions.

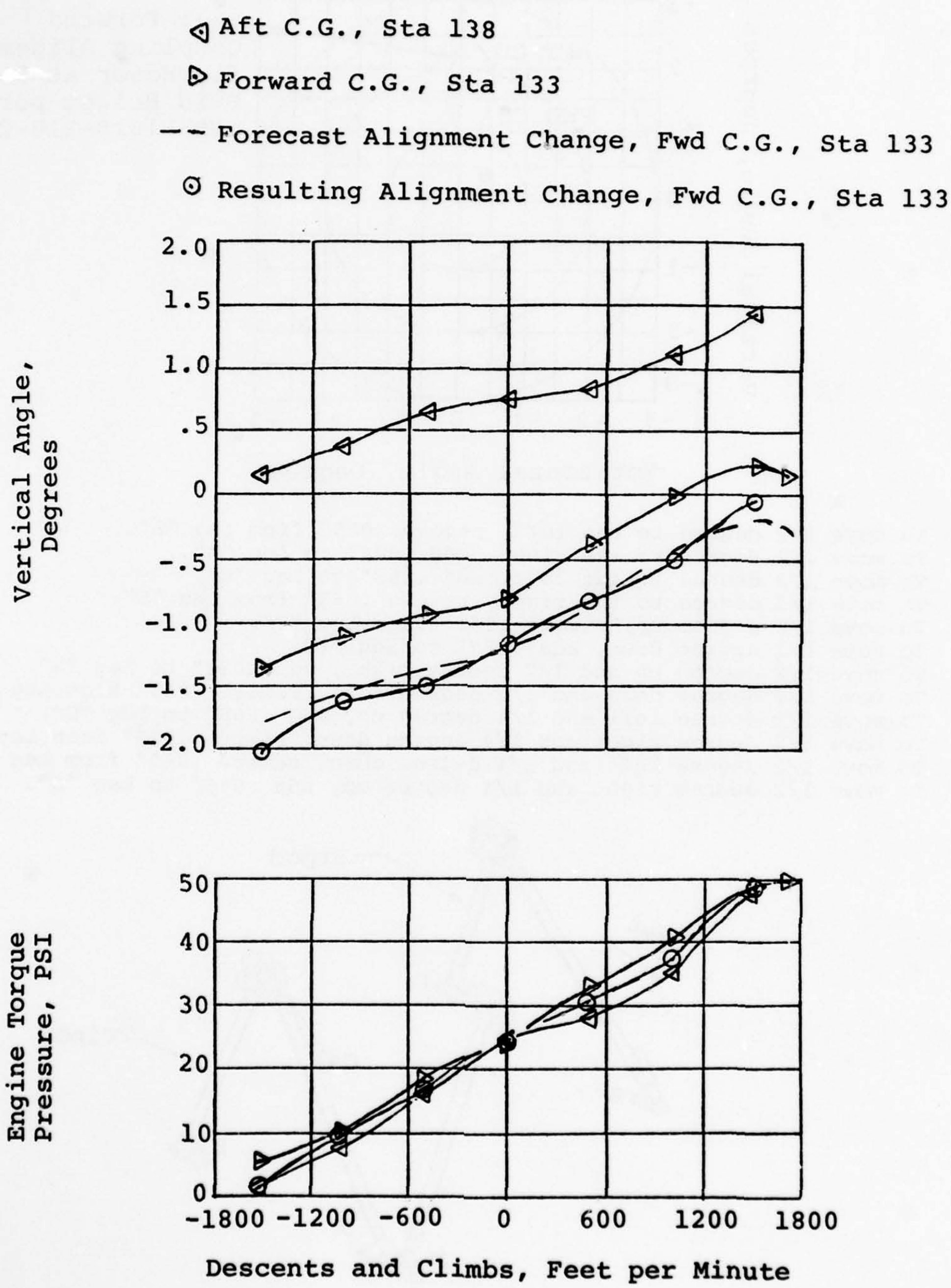


Figure 25. Forward Coupling Vertical Angle During Descent and Climb, Forward and Aft C.G., 8600 Lbs G.W.

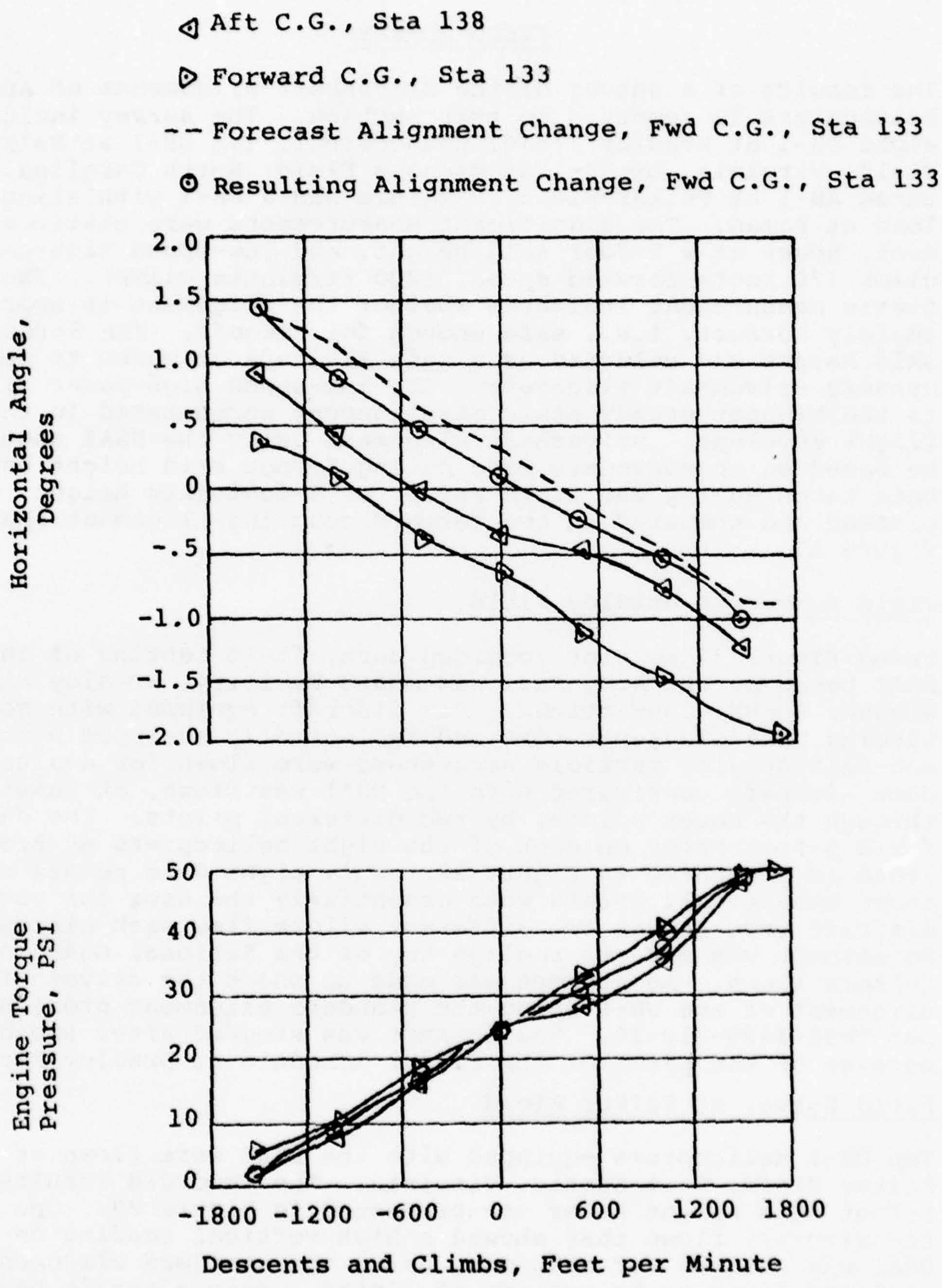


Figure 26. Forward Coupling Horizontal Angle During Descent and Climb, Forward and Aft C.G., 8600 Lbs G.W.

FIELD SURVEY

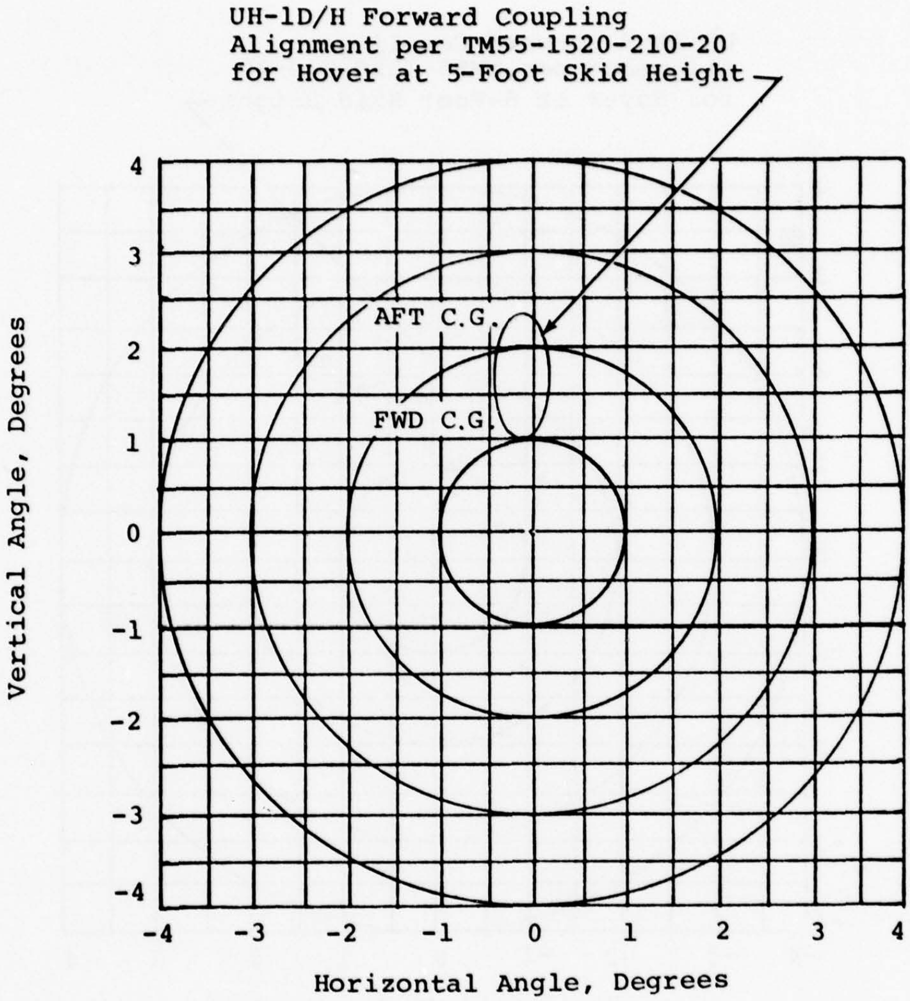
The results of a survey of the driveshaft alignments of Army helicopters is reported in this section. The survey included eight UH-1 at Bradley Field, Connecticut, ten UH-1 at Felker Field, Virginia, ten UH-1 at Simmons Field, North Carolina, three AH-1 at Felker Field, Virginia and a UH-1 with sling load at Kaman. The significant measurements were static alignment, hover at a 5-foot skid height, and low-speed high-power climb (70 knots forward speed, 1000 ft/minute climb). The static measurement indicates whether the alignment is approximately correct, i.e., safe enough for takeoff. The 5-foot skid height was selected as a safe altitude at which to measure dynamic driveshaft alignment. The low-speed high-power climb is the highest steady state misalignment encountered in the flight envelope. Driveshaft alignment using the DSAI should be based on measurements made during 5-foot skid height hover. Data taken during the field survey at 5-foot skid height were plotted and compared on the forward coupling alignment chart, Figure 27.

Field Survey at Bradley Field

Using Figure 27 to plot recorded data, field testing of the DSAI began at the Army National Guard Facility, Bradley Field, Windsor Locks, Connecticut. Six aircraft equipped with self-purging particle separators and two normally equipped with the non-self-purging particle separators were flown for evaluation. Each aircraft configured with the DSAI was flown, at least through the hover points, by two different pilots. The data for a 5-foot hover on each of the eight helicopters at Bradley Field is presented in Figure 28. Only eight data points are shown because all points were essentially the same for each aircraft even though two different pilots flew each aircraft. No attempt was made to realign any of the National Guard helicopters flown. An attempt was made to check the driveshaft alignment of one UH-1 using the standard alignment procedure per TM55-1520-210-20. The attempt was stopped after two days because of the press of the flight schedule at Bradley Field.

Field Survey at Felker Field

Ten UH-1 helicopters equipped with the DSAI were flown at Felker Field, Fort Eustis, Virginia. The recorded results for 5-foot skid height hover are presented in Figure 29. One of the aircraft flown that showed a high vertical reading on the DSAI was checked for alignment using the standard alignment tool and found to be outside of limits. This aircraft had approximately 964 hours since the last known alignment. An



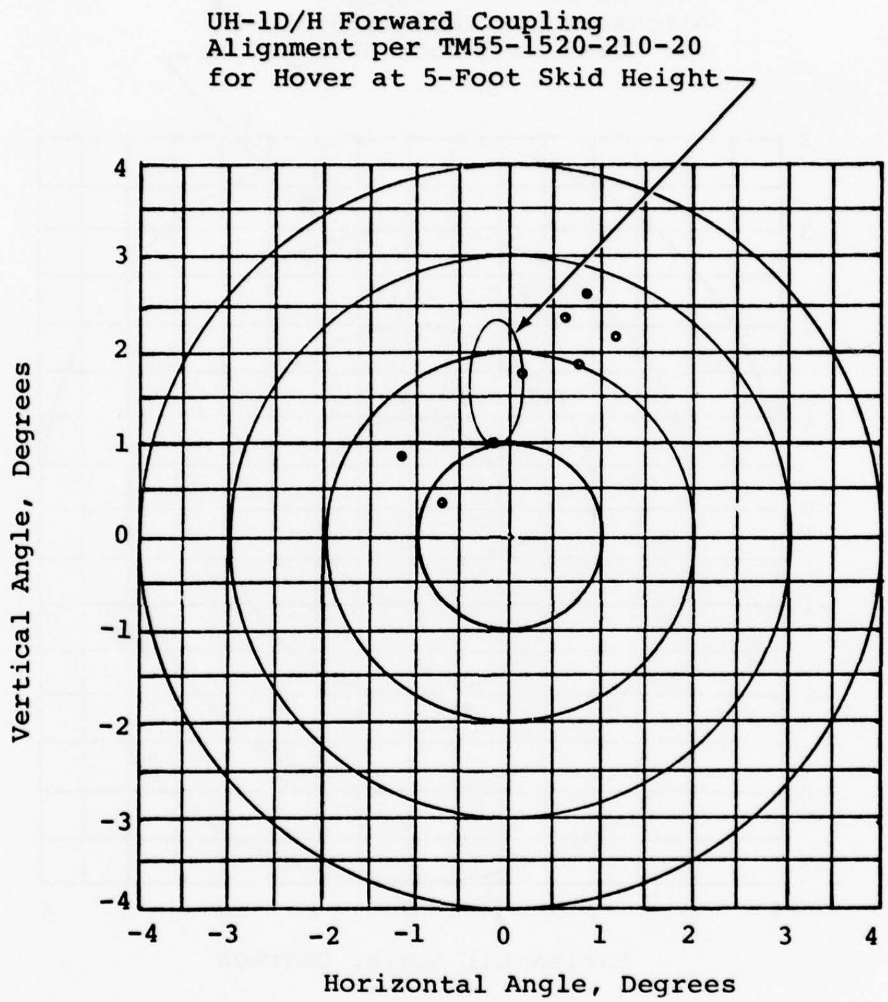
1. Enter Gross Weight__________________________.

2. Enter Center of Gravity ______________________.

3. Plot data from 5-foot hover.

4. Vertical angle is positive when the transmission end is above the engine end. Horizontal angle is positive when the transmission end is to the right of the engine ene.

Figure 27. Forward Coupling Alignment Chart.



Gross Weight: Range from 7231 lbs to 7726 lbs.

Center of Gravity: Range from 137.0 inches to 141.7 inches.

Plotted data from 5-foot hover.

Figure 28. Eight UH-1 Helicopters Flown at Bradley Field.

alignment change was made using the shim curve data developed at Kaman. This was followed by a standard alignment check for verification and the aircraft was reflown for evaluation.

Both alignment tools showed that the aircraft was aligned within tolerance after the shim change. Figure 30 presents the data recorded at a 5-foot skid height hover both before and after the alignment change. Two other aircraft that were flown with the DSAI and found within limits were checked using the standard alignment tool and procedures and showed good agreement between both alignment tools.

Field Survey at Simmons Field

Further field evaluation was conducted at Simmons Field, Fort Bragg, North Carolina, using 10 additional UH-1 aircraft. Figure 31 presents the data for a 5-foot skid height hover. The average airframe time for aircraft flown was 4416 hours at Felker Field and 706 hours at Simmons Field, indicating that the data represent a wide cross section of UH-1 aircraft. No attempt was made to alter the alignment of any of the aircraft at Simmons Field.

Field Survey of AH-1 Aircraft at Felker Field

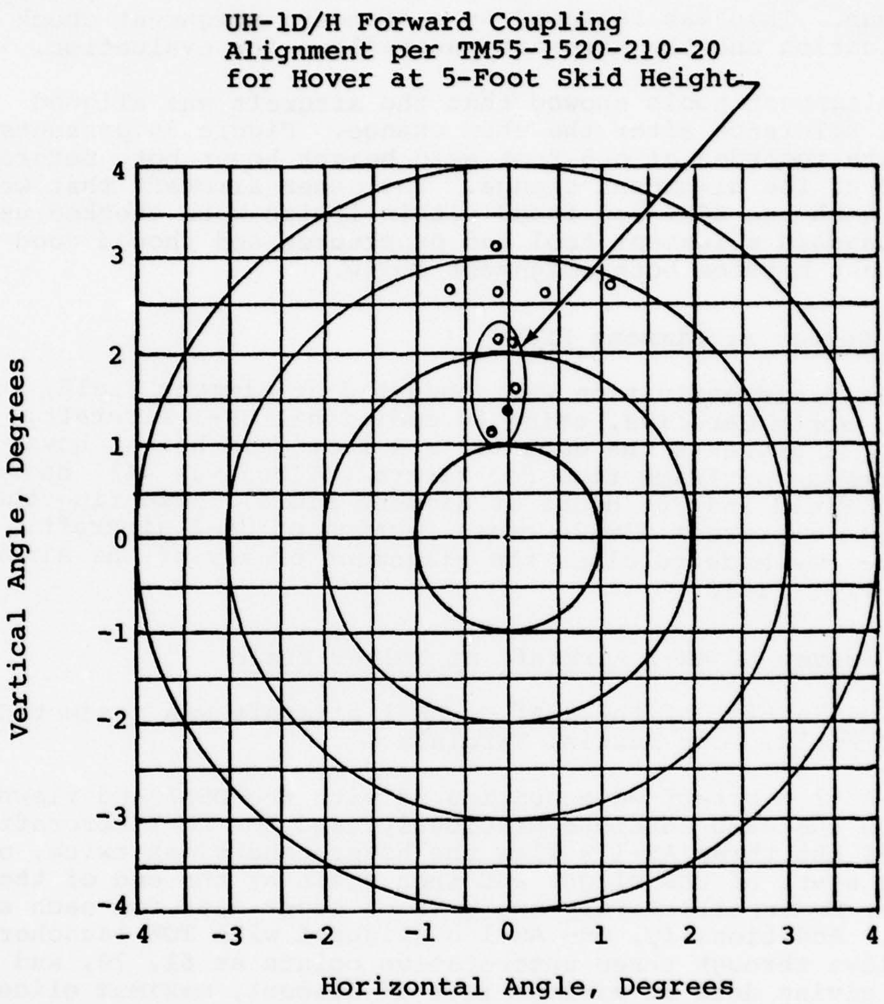
Field evaluation of the DSAI on AH-1 aircraft was conducted at Felker Field, Fort Eustis, Virginia.

Three AH-1 aircraft were configured with the DSAI and flown through the same envelope previously used for UH-1 aircraft. Each of the three AH-1's flew the hover conditions twice, once at the start of the flight and then again at the end of the flight, giving effectively two sets of hover data for each aircraft. Additionally, one AH-1 configured with TOW launchers was flown through three autorotative points at 61, 70, and 99 knots, giving data at minimum rate of descent, maximum glide angle, and the 70-knot point which was common to all previous measurements. A fourth AH-1 was configured with the DSAI but flight testing was cancelled due to bad weather conditions. A fifth and the last AH-1 available at Felker Field was down for maintenance and not expected to be in an up status for some time.

Figure 32 presents a summary of the hover data from the three AH-1 aircraft flown at Felker Field.

UH-1 Evaluation With Sling Load at Kaman

The alignment during flight with an external sling load on UH-1

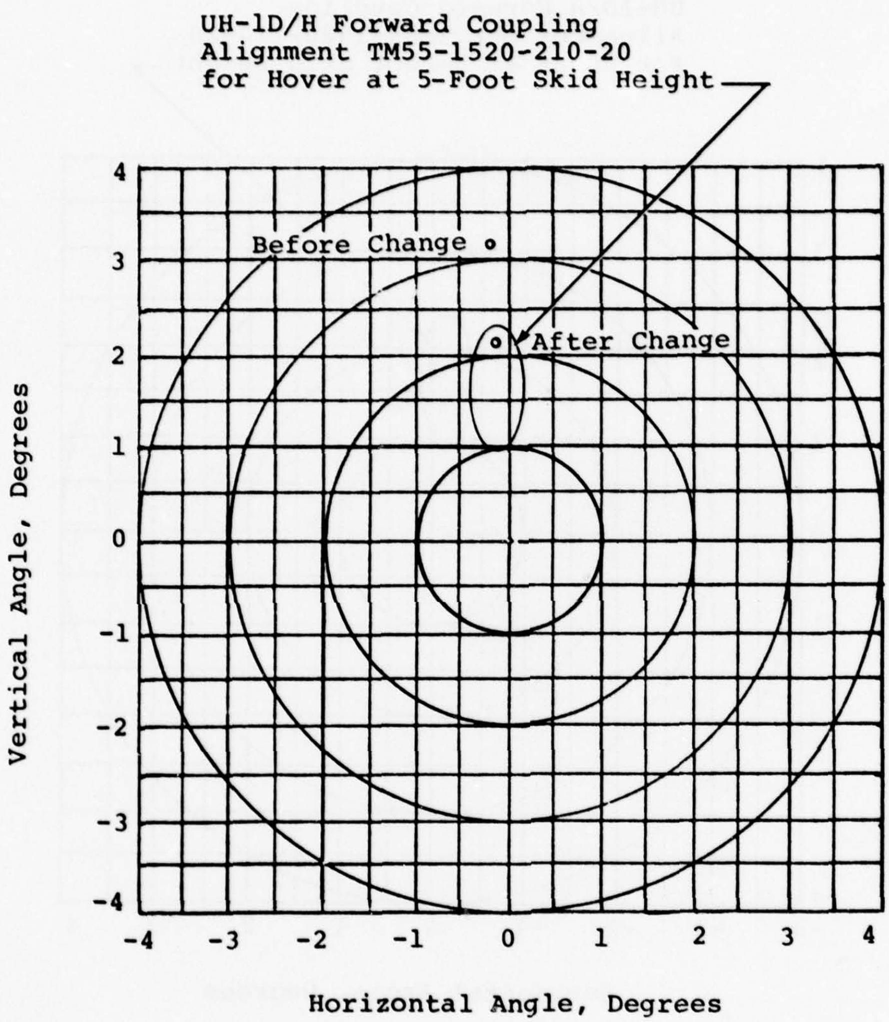


Gross Weight: Range from 6989 lbs to 7413 lbs.

Center of Gravity: Range from 139.8 inches to 144.6 inches.

Plotted data from 5-foot hover.

Figure 29. Ten UH-1 Helicopters Flown at Felker Field.

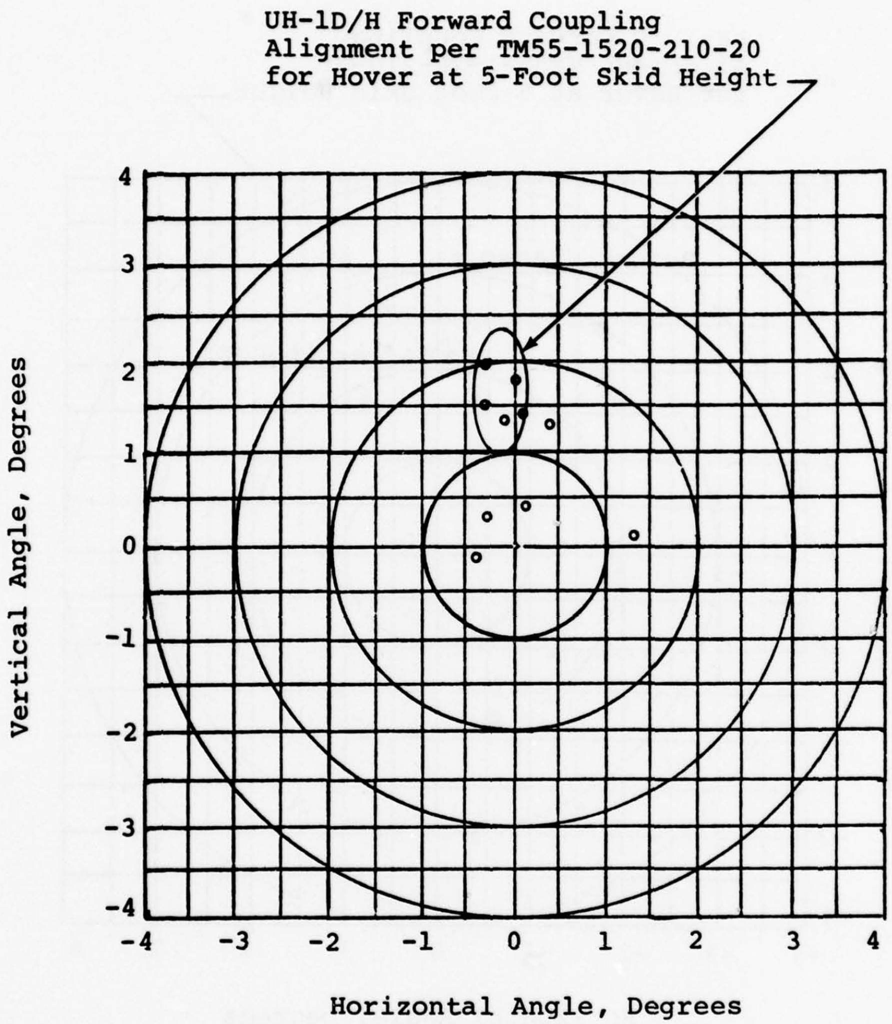


Gross Weight 7180.

Center of Gravity 139.26.

Data from 5-foot hover.

Figure 30. UH-1 Flown Before and After Alignment Change - Felker Field.

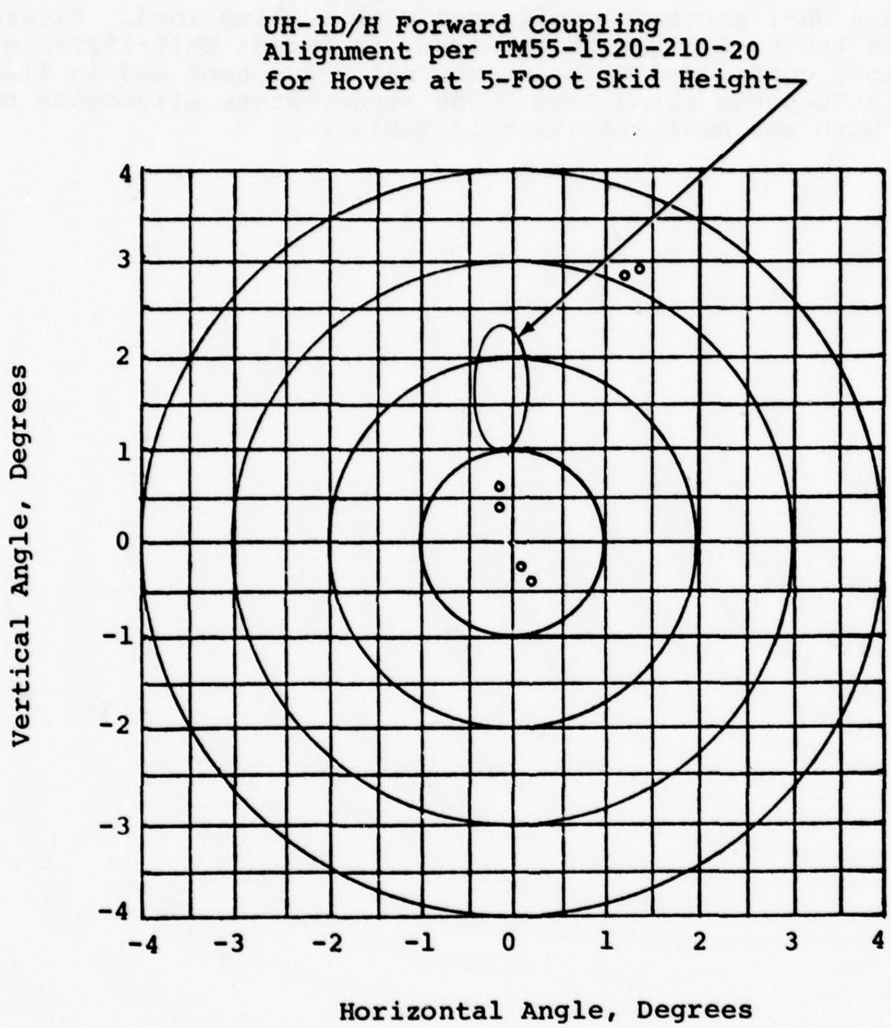


Gross Weight: Range from 7265 lbs to 7638 lbs.

Center of Gravity: Range from 137.01 inches to 139.5 inches.

Plotted data from 5-foot hover.

Figure 31. Ten UH-1 Helicopters Flown at Simmons Field.



Gross Weight: Range from 7007 lbs to 8793 lbs.

Center of Gravity: Range from 197.2 inches to 199.5 inches.

Plotted data from 5-foot hover.

Figure 32. Three AH-1 Helicopters Flown at Felker Field.

aircraft was thought to be possibly critical to shaft alignment. A contract modification was negotiated to evaluate the DSAI on a UH-1 aircraft configured with a sling load. Figure 33 shows the UH-1 aircraft at Kaman, in normal TM55-1520-210-20 alignment, configured with an external cargo hook and in flight with a 2000-pound sling load. The steady state alignments recorded with the DSAI are given in Table 2.

TABLE 2. SLING-LOAD TEST DATA

SLING LOAD TEST CONDITIONS	WITHOUT SLING LOAD 7413 lbs GW C.G. Sta. 136			WITH SLING LOAD 9413 lbs GW C.G. Sta. 136		
	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)
Hover at 20 Feet	+1.09	-.23	32	+1.58	-.75	42
70-Knot Level Flight	+1.06	-.05	20	+1.39	-.41	30
70-Knot Right Turn	+1.04	-.05	20	+1.37	-.46	30
70-Knot Left Turn	+1.03	-.04	20	+1.31	-.11	27
1000 Feet/Minute Climbs at 70 Kn	+1.29	-.46	30	+1.84	-.92	50
1000 Feet/Minute Descent at 70 Kn	+ .83	+.52	9	+ .94	+.48	7
Climb & Departure from Hover	+1.59	-.07	29	+2.23	-.76	47
Approach to a Hover	+ .59	+.28	17	+1.63	-.22	41
Right Hovering Turn	+1.08	0	29	+1.63	-.68	42
Left Hovering Turn	+1.08	-.11	29	+1.73	-.72	45

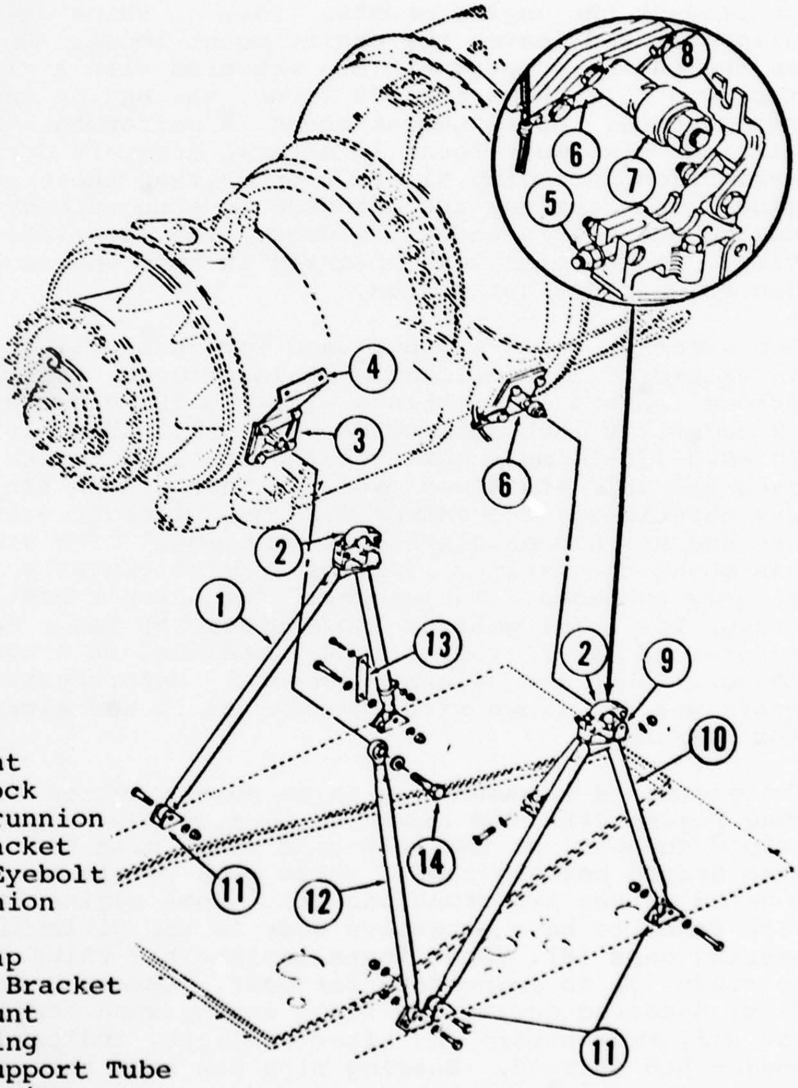
Figure 33. Army UH-1H with a 2000-Pound Sling Load.

FIELD SURVEY OBSERVATIONS

Observations were made during the field survey concerning the engine mount shim approach to driveshaft alignment. The shims are subject to having the material around the bolt holes torn or worn away, thus allowing the shims to be squeezed out from underneath the engine mounts. Loss of shims changes driveshaft alignment and leaves the engine mount loose. Loose shims found in the engine compartment are measured with a micrometer and replaced. If shims are not found, the engine mount is simply retightened. No alignment check is performed. Loose and missing shims were found in several aircraft during field evaluation, including aircraft other than those surveyed. Engine mount fittings are attached to structure by bolts which engage nut plates under the deck. The nut plates wear out with time. Loose bolts were observed in some engine compartments due to worn-out nut plates.

One aircraft which was not used for this evaluation had shims in excess of that allowable at location D, (see Figure 17). Tripod inboard leg fittings with P/N 205-060-139-1 should not exceed 0.250 inch shim thickness. All other fittings (P/N 205-060-135-1) must not exceed 0.300 inch thickness. In this case the shim stack was over 3/4 inch. When the crew chief was questioned, the answer was "The aircraft was received this way and has had no driveshaft problems." The second question was about the maximum limit of shim thickness which was obviously exceeded. The answer: "We haven't had any problem except for shims getting loose under the leg. We check it before and after every flight. Besides, it's too much trouble to go through the alignment check." Unfortunately this aircraft was not flown with the DSAI as it was always scheduled for missions.

The engine is suspended at three points by the engine mount, (See Figure 34). The bipod support, on the right-hand side, and tripod support, on the left-hand side, both have pillow blocks with hinged bearing caps. These caps retain bearings (7) mounted on the two trunnions (6). Some engine installations were found to have excessive wear in the pillowblocks (2) and bearing caps (8). Some installations had shims around the bearings (7) to compensate for wear. Excess bearing slop was first detected during the field survey when static alignment was different before and after a flight, indicating that the engine had shifted. Bearing slop can have the same effect on alignment as a shim change, depending on the direction of mount forces. The effect on dynamic alignment would only be seen under dynamic conditions.



1. Bipod Mount
2. Pillow Block
3. Forward Trunnion
4. Cambox Bracket
5. Latching Eyebolt
6. Main Trunnion
7. Bearing
8. Bearing Cap
9. Bellcrank Bracket
10. Tripod Mount
11. Deck Fitting
12. Forward Support Tube
13. Support Spring
14. Retaining Bolt

Figure 34. Engine Mount Installation.

In order to test the usability of the DSAI, alignment on some helicopters was measured entirely by Army personnel who were instructed by other Army personnel. All users said they preferred the DSAI to the present alignment procedure. It was found that dynamic alignment can be measured at the rate of two helicopters per day without extraordinary effort. The DSAI requires the removal of the particle separator for installation of the modified baffle. The particle separator is removed every 25 hours to allow the engine to be flushed, so removal and reinstallation are familiar processes and not a problem.

Users were also receptive to the idea of using turnbuckles in the engine mount legs. Turnbuckles would eliminate shims with their attendant problems, reduce the support inventory, and allow very simple, very precise driveshaft alignment without dismantling the engine mount. This approach was very successful on the Kaman UH-2 helicopter. Study of the shim curves, Figures 18 through 23, indicates that possibly only legs E and F on Figure 17 would require turnbuckles.

Concerning present practice, the alignment procedure specified in TM55-1520-210-20 is difficult and time consuming. Alignment checks required two men for three days. Of the 31 alignments measured with the DSAI, 19 exceeded the limits of the alignment specified in the -20 manual. However, the alignment specified in the -20 manual does not result in the lowest alignment at high power where damage is most likely to occur. The alignment resulting from Bell Helicopter Company Service Bulletin No. 205-76-9 (Appendix B) was evaluated. The changes specified in the bulletin would reduce misalignment at high power somewhat, but further misalignment reduction at high power can be achieved.

The field survey experience indicates that the DSAI can be improved. All threads in the A-frame should incorporate inserts to increase thread life. All A-frame and dogleg attaching bolts should be the same size. All electronic adjusting devices should have a locking provision. The cables from the multi-vits have swaged end fittings at the lead-ins to the demodulator box. One end fitting failed, indicating that the swaged end fitting is too weak for the helicopter vibratory environment. The digital meter box would be improved if it could be reduced in size, perhaps by moving parts to the demodulator box.

The voltage polarity on one UH-1 helicopter was found to be reversed, i.e., standard positive had been hooked up to negative and, of course, standard negative was positive. This damaged demodulator box components. All subsequent testing

included a test for polarity before attaching the DSAI 28 V power cable.

The DSAI has a provision to inspect and correct the zero-degree measurement by inserting a ceramic spacer between the multi-vit and the target plate, rotating the strut assembly until both the multi-vit and the target plate are in contact with the ceramic spacer, and adjusting a screw until the digital panel meter reads 0.00 degrees. Techniques should be developed that would allow inspection and correction of alignment readings at other angle measurements, such as ±2 degrees. The present design has a drift with time, possibly due to temperature increase. Measured drift during bench checks was 0.2 degree per hour of use. A possible solution might be better cooling provision.

Table 3 of this report presents a summary of the conditions flown and measurements made during field evaluation at Bradley Field, Felker Field, and Simmons Field together with the aircraft serial number, weight and balance, total airframe hours, and the time since the last known alignment. Transient alignments were observed but not recorded. They are dependent on pilot technique to a large degree. The scatter in observed alignment plus the effects of pilot technique indicate that forward couplings encounter severe misalignments, especially during transition from hover to low-speed high-power climb and during low-speed high-power climb.

TABLE 3. FIELD SURVEY DATA

UH-1H AIRCRAFT	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
63-12975	2' Hov.	+1.40	+.01	29	7524	137	3708	180
	5' Hov.	+1.64	+.15	31				
	10' Hov.	+1.63	+.19	33				
	15' Hov.	+2.27	+.20	32				
	5' Hov.	+1.79	+.17	30				
	5' Hov.	+1.74	+.12	30				
	2' Hov.	+1.37	+.09	29				
	5' Hov.	+1.16	+.08	29				
	10' Hov.	+1.72	+.08	29				
	15' Hov.	+2.38	+.04	28				
	5' Hov.	+1.41	+.13	28				
	5' Hov.	+1.47	+.10	30				
	Static	+ .55	+.98	--				
66-16510								
	– Static	-.15	+.68	--	7508	140.7	4414	271
	2' Hov.	+1.25	-.34	30				
	– 5' Hov.	+1.18	-.44	32				
	10' Hov.	+1.37	-.50	34.5				
	70 Kn	+1.01	-.28	21				
	70 Kn – 1000'/min.	+1.60	-.78	34				
	70 Kn 1000'/min.	+ .63	+.22	9.5				
	70 Kn Auto	+ .38	+.69	0				
	5' Hov.	+1.02	-.48	30.5				
70-16515								
	– Static	-65	+.60	--	7434	138.8	1125.3	1125.3
	2' Hov.	+.49	-.72	27				
	– 5' Hov.	+.56	-.76	29				
	10' Hov.	+.50	-.79	30.5				
	70 Kn	+.35	-.40	20				
	70 Kn – 1000'/Min.	+.57	-.79	31				
	70 Kn 1000'/Min.	-.04	-.05	9				
	70 Kn Auto	-.50	+.47	0				
	5' Hov.	+.31	-.72	27				

–Data used in statistical analysis

TABLE 3 (continued)

UH-1H AIRCRAFT	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
72-21487	— Static	+ .56	+2.34	--	7231	139.9	827.1	827.1
	2' Hov.	+1.84	+1.39	26				
	— 5' Hov.	+2.09	+1.38	27				
	10' Hov.	+2.23	+1.36	30				
	70 Kn	+1.81	+1.58	17				
	70 Kn — 1000'/Min.	+2.45	+1.15	30				
	70 Kn 1000'/Min.	+1.60	+1.86	8				
	70 Kn Auto	+1.33	+2.32	0				
	5' Hov.	+1.85	+1.29	27				
	Static	+ .71	+2.05	--				
68-15223	— Static	-1.03	+ .33	--	7557	138.7	4083.6	174.1
	2' Hov.	+ .16	- .99	29				
	— 5' Hov.	+ .48	-1.05	30				
	10' Hov.	+1.32	-1.07	30				
	70 Kn	+ .72	- .92	20				
	70 Kn — 1000'/Min.	+1.24	-1.25	32				
	70 Kn 1000'/Min.	+ .45	- .46	9				
	70 Kn Auto	+ .04	0	0				
	5' Hov.	+ .75	-1.09	30				
	Static	- .60	+ .08	--				
70-16516	— Static	+ .25	+2.20	--	7726	137.6	1134.7	1134.7
	2' Hov.	+1.39	+ .71	28				
	— 5' Hov.	+1.77	+ .74	30				
	10' Hov.	+2.10	+ .61	32				
	70 Kn	+ .94	+1.18	10				
	70 Kn — 1000'/Min.	+2.07	+ .25	33				
	70 Kn 1000'/Min.	+1.44	+ .76	20				
	70 Kn Auto	+ .78	+1.72	0				
	5' Hov.	+1.49	+ .57	29				
	Static	+ .30	+2.04	--				

— Data used in statistical analysis

TABLE 3 (continued)

UH-1H AIRCRAFT 69-15127	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
	– Static	+1.00	+1.58	--	7257	139.2	2385.3	2385.3
	2' Hov.	+2.25	+ .70	28				
	– 5' Hov.	+2.33	+ .65	29				
	10' Hov.	+2.50	+ .54	32				
	70 Kn	+2.24	+ .67	21				
	– 1000'/Min.	+2.62	+ .28	34				
	70 Kn							
	1000'/Min.	+1.84	+1.11	9				
	70 Kn							
	Auto	+1.54	+1.53	0				
	5' Hov.	+2.41	+ .61					
	Static	+1.02	+1.63	--				
64-13768								
	– Static	+ .50	+2.33	--	7392	141.7	3949.	699
	2' Hov.	+2.04	+1.09	26				
	– 5' Hov.	+2.19	+1.04	27				
	10' Hov.	+2.54	+ .86	30				
	70 Kn	+2.33	+1.04	20				
	70 Kn							
	– 1000'/Min.	+2.80	+ .62	31				
	70 Kn							
	1000'/Min.	+1.83	+1.51	9				
	70 Kn							
	Auto	+1.62	+2.10	0				
	5' Hov.	+2.50	+ .90	27				
	Static	+ .68	+2.44	--				
64-13897								
	– Static	+1.23	+1.07	--	7005	141.8	4125.1	164.1
	2' Hov.	+2.61	- .11	26				
	– 5' Hov.	+2.63	- .10	27.5				
	10' Hov.	+3.11	- .30	29				
	70 Kn	+2.78	- .05	28				
	70 Kn							
	– 1000'/Min.	+3.20	- .39	30				
	70 Kn							
	1000'/Min.	+2.57	+ .24	14				
	70 Kn							
	Auto	+2.11	+1.07	0				
	5' Hov.	+2.88	- .25	28				
	Static	+1.20	+ .94	--				

– Data used in statistical analysis

TABLE 3 (continued)

UH-1H AIRCRAFT	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
66-1140								
	– Static	- .45	+1.20	--	7051	142.6	4070.2	1245.9
	2' Hov.	+1.44	+ .03	26				
	– 5' Hov.	+1.48	- .08	28				
	10' Hov.	+1.52	- .14	30				
	70 Kn	+1.16	+ .13	20				
	70 Kn – 1000'/Min.	+1.55	- .20	28				
	70 Kn 1000'/Min.	+ .86	+ .61	8				
	70 Kn Auto	+ .53	+1.22	0				
	5' Hov.	+1.44	0	26				
	Static	- .35	+1.17	--				
66-16305								
	– Static	+ .82	+1.78	--	7073	140.5	4347.1	882.2
	2' Hov.	+2.31	+ .53	28				
	– 5' Hov.	+2.57	+ .48	30				
	10' Hov.	+2.98	+ .41	31				
	70 Kn	+2.54	+ .74	21				
	70 Kn – 1000'/Min.	+2.85	+ .33	30				
	70 Kn 1000'/Min.	+2.25	+1.11	12				
	70 Kn Auto	+1.92	+1.63	0				
	5' Hov.	+2.44	+ .53	28				
	Static	+ .77	+1.68	--				
68-15239								
	– Static	- .45	+1.11	--	7152	144.6	4304.1	1002.8
	2' Hov.	+1.27	+ .04	25				
	– 5' Hov.	+1.60	+ .05	29				
	10' Hov.	+1.87	+ .02	27				
	70 Kn	+1.42	+ .20	17				
	70 Kn – 1000'/Min.	+1.82	- .24	28				
	70 Kn 1000'/Min.	+1.01	+ .53	10				
	70 Kn Auto	+.72	+1.10	0				
	5' Hov.	+1.37	- .07	25				
	Static	- .42	+1.06	--				

– Data used in statistical analysis

TABLE 3 (continued)

UH-1H AIRCRAFT 69-15455	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
	BEFORE ALIGNMENT							
	— Static	+ .77	+1.09	--	7180	139.3	2620.1	964
	2' Hov.	+2.78	- .04	27				
	— 5' Hov.	+3.16	- .12	30				
	10' Hov.	+3.41	- .19	31				
	70 Kn	+3.03	+ .03	19				
	70 Kn — 1000'/Min.	+3.40	- .34	29				
	70 Kn 1000'/Min.	+2.62	+ .32	10				
	70 Kn Auto	+2.37	+1.05	0				
	5' Hov.	+3.21	- .29	29				
	Static	+ .95	+ .92	--				
69-15455	AFTER REALIGNMENT							
	— Static	- .16	+ .70	--	7180	139.3		0
	2' Hov.	+2.52	- .31	27				
	— 5' Hov.	+2.27	- .38	29				
	10' Hov.	+2.63	- .46	30				
	70 Kn	+2.37	- .12	18				
	70 Kn — 1000'/Min.	+2.56	- .56	28				
	70 Kn 1000'/Min.	+2.10	+ .24	9				
	70 Kn Auto	+1.52	+ .68	0				
	5' Hov.	+2.77	- .34	28				
	Static	0	+ .87	--				
69-16270								
	— Static	+ .62	+2.20	--	6989	141.75	4698.9	763.5
	2' Hov.	+2.47	+1.19	26				
	— 5' Hov.	+2.74	+1.10	28				
	10' Hov.	+2.98	+1.09	30				
	70 Kn	+2.91	+1.22	20				
	70 Kn — 1000'/Min.	+3.21	+ .84	31				
	70 Kn 1000'/Min.	+2.63	+1.68	8				
	70 Kn Auto	+2.27	+2.21	0				
	5' Hov.	+2.80	+1.03	28				
	Static	+ .47	+2.18	--				

— Data used in statistical analysis

TABLE 3 (continued)

UH-1H AIRCRAFT	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
66-17037	— Static	- .69	+1.20	--	7413	139.64	3587.6	519.8
	2' Hov.	+ .71	- .12	30				
	— 5' Hov.	+1.09	- .23	33				
	10' Hov.	+1.23	- .29	33				
	70 Kn	+ .91	- .06	21				
	70 Kn — 1000'/Min.	+1.31	- .40	32				
	70 Kn 1000'/Min.	+ .50	+ .49	9				
	70 Kn Auto	+ .33	+1.04	0				
	5' Hov.	+ .81	- .22	28				
	Static	- .58	+1.15	--				
66-1043								
	Static	+ .72	+ .68	--	7166	139.9	7071.3	2222.7
	2' Hov.	+2.54	- .50	30				
	5' Hov.	+2.72	- .54	31				
	10' Hov.	+2.81	- .60	33				
	2' Hov.	+2.56	- .50	30				
	5' Hov.	+2.73	- .56	31				
	10' Hov.	_2.81	- .59	33				
	Static	∓ .90	+ .59	--				
70-15851								
	2' Hov.	+1.21	+ .14	26	7156	139.8	3212	0
	5' Hov.	+2.12	+ .13	27				
	10' Hov.	+2.61	+ .06	27				
	70 Kn	+1.46	+ .32	27				
	70 Kn — 1000'/Min.	+1.76	- .05	28				
	70 Kn 1000'/Min.	+1.00	+ .67	10				
	70 Kn Auto	+ .93	+1.14	0				
	— 5' Hov.	+1.53	+ .13	27				
	— Static	0	+1.14	--				

— Data used in statistical analysis

TABLE 3 (continued)

UH-1H AIRCRAFT 73-21775	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
	– Static	+ .52	+ .99	--	7452	137.5	563	563
	2' Hov.	+1.40	- .29	27				
	– 5' Hov.	+1.50	- .31	29				
	10' Hov.	+1.58	- .33	30				
	70 Kn	+1.49	- .22	20				
	70 Kn – 1000'/Min.	+2.03	- .62	32.5				
	70 Kn 1000'/Min.	+1.08	+ .31	9				
	Auto	+ .99	+ .79	0				
	5' Hov.	+ .58	+ .96	29				
	Static	+ .58	+ .96	--				
73-21774								
	– Static	- .97	+3.06	--	7570	137.99	582.5	582.5
	2' Hov.	- .12	+1.46	30				
	– 5' Hov.	+ .13	+1.33	32				
	10' Hov.	+ .21	+1.29	34.5				
	70 Kn	+ .12	+1.64	21				
	70 Kn – 1000'/Min.	+ .56	+ .88	34				
	70 Kn 1000'/Min.	- .28	+2.37	7				
	70 Kn Auto	- .53	+2.83	0				
	5' Hov.	+ .17	+1.34	33				
	Static	- .70	+3.02	--				
69-15688								
	– Static	- .79	+1.34	--	7361	138.74	662.8	662.8
	2' Hov.	+ .34	+ .21	28				
	– 5' Hov.	+ .36	+ .06	30				
	10' Hov.	+ .43	- .04	32				
	70 Kn	+ .21	+ .34	20				
	70 Kn – 1000'/Min.	+ .64	- .08	32				
	70 Kn 1000'/Min.	- .08	+ .69	12				
	70 Kn Auto	- .43	+1.33	0				
	5' Hov.	+ .30	+ .11	30				
	Static	- .74	+1.35	--				

– Data used in statistical analysis

TABLE 3 (continued)

UH-1H AIRCRAFT 71-20251	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
	– Static	+ .71	+1.11	--	7294	138.07	1014	*
	2' Hov.	+1.75	- .23	26				
	– 5' Hov.	+1.96	- .34	28				
	10' Hov.	+2.03	- .40	30				
	70 Kn	+1.76	- .08	19				
	70 Kn – 1000'/Min.	+2.36	- .57	30				
	70 Kn 1000'/Min.	+1.46	+ .45	8				
	70 Kn Auto	+1.36	+ .92	0				
	5' Hov.	+1.83	- .19	26				
	Static	+ .79	+ .98	--				
69-15248								
	– Static	- .33	+1.54	--	7599	137.01	784	370
	2' Hov.	+1.24	+ .18	27				
	5' Hov.	+1.45	+ .18	30				
	10' Hov.	+1.47	+ .01	31				
	70 Kn	+ .76	+ .39	17				
	70 Kn – 1000'/Min.	+1.26	- .01	30				
	70 Kn 1000'/Min.	+ .50	+ .82	9				
	70 Kn Auto	+ .13	+1.37	0				
	– 5' Hov.	+1.18	+ .18	30				
	Static	- .15	+1.44	--				
67-17238								
	– Static	+ .13	+1.09	--	7448	139.5	3944.7	346.2
	2' Hov.	+1.32	+ .02	27				
	– 5' Hov.	+1.75	- .02	30				
	10' Hov.	+1.80	- .08	32				
	70 Kn	+1.47	+ .10	19				
	70 Kn – 1000'/Min.	+2.40	- .55	36				
	70 Kn 1000'/Min.	+1.18	+ .53	8				
	70 Kn Auto	+1.07	+1.12	0				
	5' Hov.	+1.29	+ .14	30				
	Static	+ .04	+1.07	--				

– Data used in statistical analysis

* Time of last alignment unknown. Entry made in *Log Book* of a center deck repair a few months prior to this flight, however, no airframe hours noted.

TABLE 3 (Continued)

UH-1H AIRCRAFT	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
70-16413	— Static	- .27	+ .94	--	7520	137.01	1417.5	47.5
	2' Hov.	+ .32	- .25	29				
	— 5' Hov.	+ .38	- .29	30				
	10' Hov.	+ .44	- .36	32.5				
	70 Kn	+ .06	+ .03	19				
	70 Kn — 1000'/Min.	+ .83	- .31	31				
	70 Kn 1000'/Min.	- .12	+ .12	9.5				
	70 Kn Auto	- .45	+ .89	0				
	5' Hov.	-.30	- .35	30				
	Static	- .27	+1.30	--				
69-15866	— Static	-1.06	+ .88	--	7638	137.76	897	897
	2' Hov.	- .25	- .25	27				
	— 5' Hov.	- .03	- .47	29				
	10' Hov.	- .09	- .61	32				
	70 Kn	- .16	- .20	18				
	70 Kn — 1000'/Min.	+ .33	- .69	31				
	70 Kn 1000'/Min.	- .50	+ .32	6				
	70 Kn Auto	- .63	+ .80	0				
	5' Hov.	+ .10	- .48	29				
	Static	-1.23	+ .85	--				
69-15054	— Static	- .17	+1.28	--	7483	137.94	3047.1	*
	2' Hov.	+1.06	+ .07	27				
	— 5' Hov.	+1.32	- .03	30				
	10' Hov.	+1.51	0	34				
	70 Kn	+1.16	+ .10	18				
	70 Kn — 1000'/Min.	+1.85	- .07	35				
	70 Kn 1000'/Min.	+ .87	+ .26	10				
	70 Kn Auto	+ .68	+ .92	0				
	5' Hov.	+1.32	0	29				
	Static	+ .06	+1.13	--				

— Data used in statistical analysis.

* Time of last alignment unknown. Crew chief stated alignment work done approximately one year ago, but no entry could be found in log book.

TABLE 3 (continued)

UH-1H AIRCRAFT ----302	COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
	Static	+ .55	+1.60	--	7265	138.6	1632	*
	2' Hov.	+1.28	+ .46	24				
	5' Hov.	+1.28	+ .45	28				
	10' Hov.	+1.55	+ .45	30				
	5' Hov.	+1.21	+ .38	31				
	Static	+ .56	+1.42	--				
PROD AH-1S AIRCRAFT 76-22572								
	Static	- .94	+1.17	--	8459	197.2	97.3	97.3
	2' Hov.	- .55	+ .09	64%				
	5' Hov.	- .41	+ .10	68%				
	10' Hov.	- .25	- .05	72%				
	70 Kn	- .11	+ .50	44%				
	70 Kn – 1000'/Min.	+ .21	+ .20	62%				
	70 Kn 1000'/Min	- .15	+ .81	26%				
	61 Kn Auto	- .05	+1.32	0				
	70 Kn Auto	- .16	+1.23	0				
	99 Kn Auto	- .34	+1.30	0				
	2' Hov.	- .26	+ .10	62%				
	5' Hov.	- .25	+ .05	65%				
	10' Hov.	- .11	+ .04	70%				
	Static	- .83	+1.14	--				

– Data used in statistical analysis

* Time of last alignment unknown. Aircraft has a history of overhaul several times, including crash damage, but no airframe time is noted.

TABLE 3 (continued)

AH-1S 70-16082 COND.	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	TORQUE METER (Psi)	GROSS WEIGHT (Lbs)	C.G. STATION (Inches)	TOTAL AIRFRAME TIME (Hours)	TIME SINCE LAST ALIGNMENT (Hours)
Static	- .41	+1.17	--	8793	199.5	552.0	253.7
2' Hov.	+ .39	- .03	35				
5' Hov.	+ .43	- .10	38				
10' Hov.	+ .50	- .17	39.5				
70 Kn	+ .78	+ .39	21				
70 Kn 1000'/Min.	+1.37	- .93	45				
70 Kn 1000'/Min.	+ .62	+ .79	6				
70 Kn Auto	+ .59	+ .96	0				
2' Hov.	+ .55	- .08	36				
5' Hov.	+ .55	- .16	38				
10' Hov.	+ .67	- .14	39.5				
Static	- .38	+ .85	--				
AH-1G 67-15823							
2' Hov.	+2.70	+1.43	26.5	7007	198.4	2083.9	*
5' Hov.	+2.98	+1.36	28				
10' Hov.	+3.03	+1.33	29.5				
70 Kn	+3.03	+1.97	15				
70 Kn 1000'/Min.	+3.10	+1.58	29				
70 Kn 1000'/Min.	+2.85	+2.26	6				
70 Kn Auto	+2.75	+2.45	0				
2' Hov.	+2.66	+1.37	25.5				
5' Hov.	+2.93	+1.33	28				
10' Hov.	+2.92	+1.34	29				
Static	+2.29	+2.30	--				

* Time of last alignment unknown. Log book states that an engine deck overhaul and modification were done on 25 March 1976, but no airframe time is noted. However, a repair conducted prior to overhaul and modification is noted at 1839.4 airframe hours and a subsequent repair is noted at 2015 airframe hours, placing last alignment somewhere in between.

STATISTICAL ANALYSIS OF FIELD SURVEY DATA

Statistical analysis of UH-1 forward coupling alignment was performed using normal distribution and based on a significant sample size (25 sets of data). The data were analyzed for mean value ($\bar{x}$), standard deviation (σ), mean ± 3 standard deviations ($\bar{x} \pm 3\sigma$), and coefficient of variation ($cv = \sigma/\bar{x}$). The values given by $\bar{x} \pm 3\sigma$ include 99.73 percent of a normally distributed population. The alignments analyzed were for static, hover with 5-foot skid height, and low-speed high-power climb. The data and the results of the analysis are given in Table 4. The mean values for the three alignment cases are given in Figure 35. Also shown in Figure 35 is the maximum misalignment predicted by the analysis, $\bar{x} \pm 3\sigma$, for low-speed high-power climb. The maximum misalignment predicted is 4.96 degrees.

The data were examined to evaluate the change in alignment that occurs when the UH-1 transitions from the static case to the 5-foot hover case and to low-speed high-power climb. The change in alignment angles and the analysis results are presented in Table 5.

These data were used to predict the improved alignment that would result with driveshaft alignment specified at the 5-foot hover condition, shown in Figure 36. Suggested alignments are: vertical angle -.35 degree $\pm$ .50 degree and horizontal angle +.25 degree $\pm$ .25 degree. At low-speed high-power climb, the resulting nominal alignment would be: vertical angle + .01 degree $\pm$ .5 degree, horizontal angle +.01 degree $\pm$ .25 degree.

The maximum misalignment predicted uses $\bar{x} + 3\sigma$ for the vertical angle and $\bar{x} - 3\sigma$ for the horizontal angle. The one-way use of the 3σ values is based on the observation that in no case did the vertical angle decrease or the horizontal angle increase as the helicopter transitioned from the 5-foot hover case to low-speed high-power climb. The envelope of alignment at low-speed high-power climb is thus: vertical angle = +.01 $\pm$ .5, +.55 or - 0 = + 1.06 to - .49, horizontal angle = + .01 $\pm$ .25, +0 or - .41 - + .26 to - .65. The maximum possible misalignment for the high power condition would be slightly over 1 degree.

The static alignment would be the result of change in power to zero. The nominal static alignment would be: vertical angle -1.88 degrees, horizontal angle +1.46 degrees. The resultant static misalignment angle would be 2.38 degrees. The angle appears high. However, the power is zero and no damage can occur.

TABLE 4. ANGLES AND ANALYSIS FOR THREE CONDITIONS

TAIL NO.	STATIC		5-FOOT HOVER		70 KN FWD, 1000 FT/MIN ↑	
	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	VERT. ANGLE (Degrees)	HORIZ. ANGLE (Degrees)	VERT. ANGLE (Degrees)	HORIZ ANGLE (Degrees)
66-16510	- .15	.68	1.18	- .44	1.60	- .78
70-16515	- .65	.60	.56	- .76	.57	- .79
72-21487	+ .56	2.34	2.09	+1.38	2.45	+1.15
68-15223	-1.03	.33	.48	-1.05	1.24	-1.25
70-16516	+ .25	2.20	1.77	+ .74	2.07	+ .25
69-15127	1.00	1.58	2.33	+ .65	2.62	+ .28
64-13768	+ .50	2.33	2.19	+1.04	2.80	+ .62
64-13897	+1.23	1.07	2.63	- .10	3.20	- .39
66-1140	- .45	1.20	1.48	- .08	1.55	- .20
66-16305	+ .82	1.78	2.57	+ .48	2.85	+ .33
68-15239	- .45	1.11	1.60	+ .05	1.82	- .24
69-15455	+ .77	1.09	3.16	- .12	3.40	- .34
69-15455	- .16	.70	2.27	- .38	2.56	- .56
66-16270	+ .62	2.20	2.74	1.10	3.21	+ .84
66-17037	- .69	1.20	1.09	- .23	1.31	- .40
70-15851	0	1.14	1.53	+ .13	1.76	- .05
73-21775	+ .52	.99	1.50	- .31	2.03	- .62
73-21774	- .97	3.06	.13	+1.33	.56	+ .88
69-15688	- .79	1.34	.36	+ .06	.64	- .08
71-20251	+ .71	1.11	1.96	- .34	2.36	- .57
69-15248	- .33	1.54	1.18	+ .18	1.26	- .01
67-17238	+ .13	1.09	1.75	- .02	2.40	- .55
70-16413	- .27	.94	.38	- .29	.83	- .31
69-15866	-1.06	.88	- .03	- .47	.33	- .69
69-15054	- .17	1.28	1.32	- .03	1.85	- .07
$\overline{x}$	- .0024	1.3945	1.5288	.1008	1.8908	- .142
σ^2	.4538	.4166	.76082	.39944	.80527	.34018
σ	.6737	.6455	.87225	.63201	.89737	.58325
3σ	2.0210	1.9364	2.61675	1.89604	2.69211	1.74976
$\overline{x} + 3\sigma$	2.0186	3.3310	4.14555	1.9968	4.58291	1.60776
$x - 3\sigma$	-2.0234	-.5419	1.08795	-1.79524	-.80131	-1.89176
$CV = \sigma/\overline{x}$	-280.69	.1938	.80174	.3520	1.11988	.36277

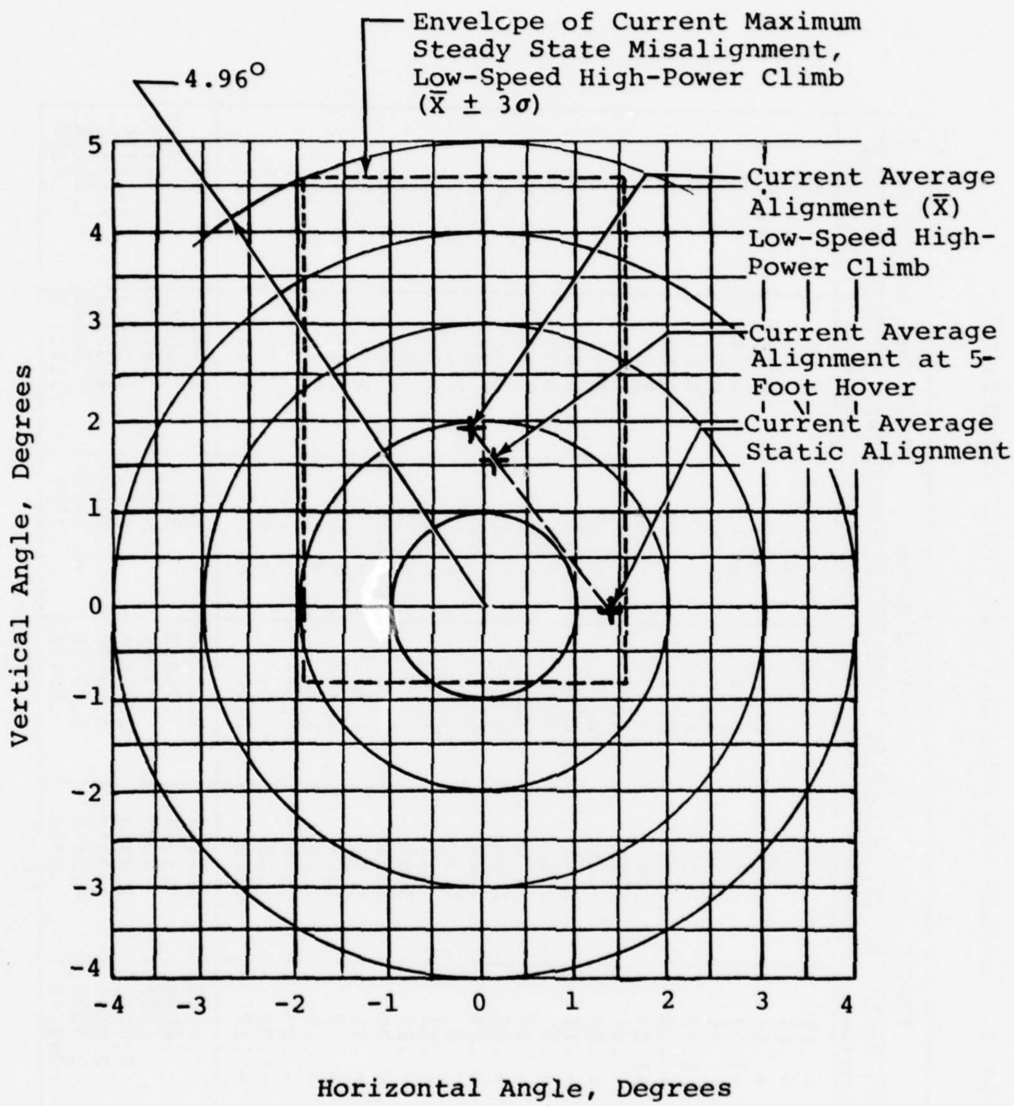


Figure 35. Average Current Alignment for Three Conditions and Maximum Expected Misalignment.

TABLE 5. CHANGE IN ANGLES AND ANALYSIS

TAIL NO.	STATIC TO 5-FT HOVER VERT. ANGLE (Degrees)	STATIC TO 5-FT HOVER HORIZ.ANGLE (Degrees)	5 FT HOVER TO 70 KN FWD 1000 FT/MIN CLIMB VERT. ANGLE (Degrees)	5 FT HOVER TO 70 KN FWD 1000 FT/MIN CLIMB HORIZ. ANGLE (Degrees)
66-16510	1.33	1.12	.42	.34
70-16515	1.21	1.36	.01	.03
72-21487	1.53	.95	.36	.23
68-15223	1.51	1.38	.76	.20
70-16516	1.52	1.46	.30	.49
69-15127	1.33	.93	.29	.37
64-13768	1.69	1.29	.61	.42
64-13897	1.40	1.17	.57	.29
66-1140	1.93	1.28	.07	.12
66-16305	1.75	1.30	.28	.15
68-15239	2.05	1.06	.22	.29
69-15455	2.43	1.08	.29	.18
69-15455	2.39	1.21	.24	.22
66-16270	2.12	1.10	.47	.26
66-17037	1.78	.97	.22	.17
70-15851	1.53	1.01	.23	.18
73-21775	.98	.68	.53	.31
73-21774	1.10	1.73	.43	.45
69-15688	1.15	1.28	.28	.14
71-20251	1.25	1.45	.40	.23
69-15248	1.51	1.36	.08	.19
67-17238	1.62	1.11	.65	.53
70-16413	.65	1.23	.45	.02
69-15866	1.03	1.35	.36	.22
69-15054	1.49	1.31	.53	.04
$\overline{x}$	1.5312	1.2068	.362	.2428
σ^2	.1837	.0464	.0342	.0184
σ	.4286	.2155	.1849	.1358
3σ	1.2858	.6464	.5547	.4073
$\overline{x} + 3\sigma$	2.8170	1.8532	.9167	.6501
$\overline{x} - 3\sigma$	.2454	.5604	-.1927	-.1645
$cv = \sigma/\overline{x}$	.27992	.1785	.5107	.5591

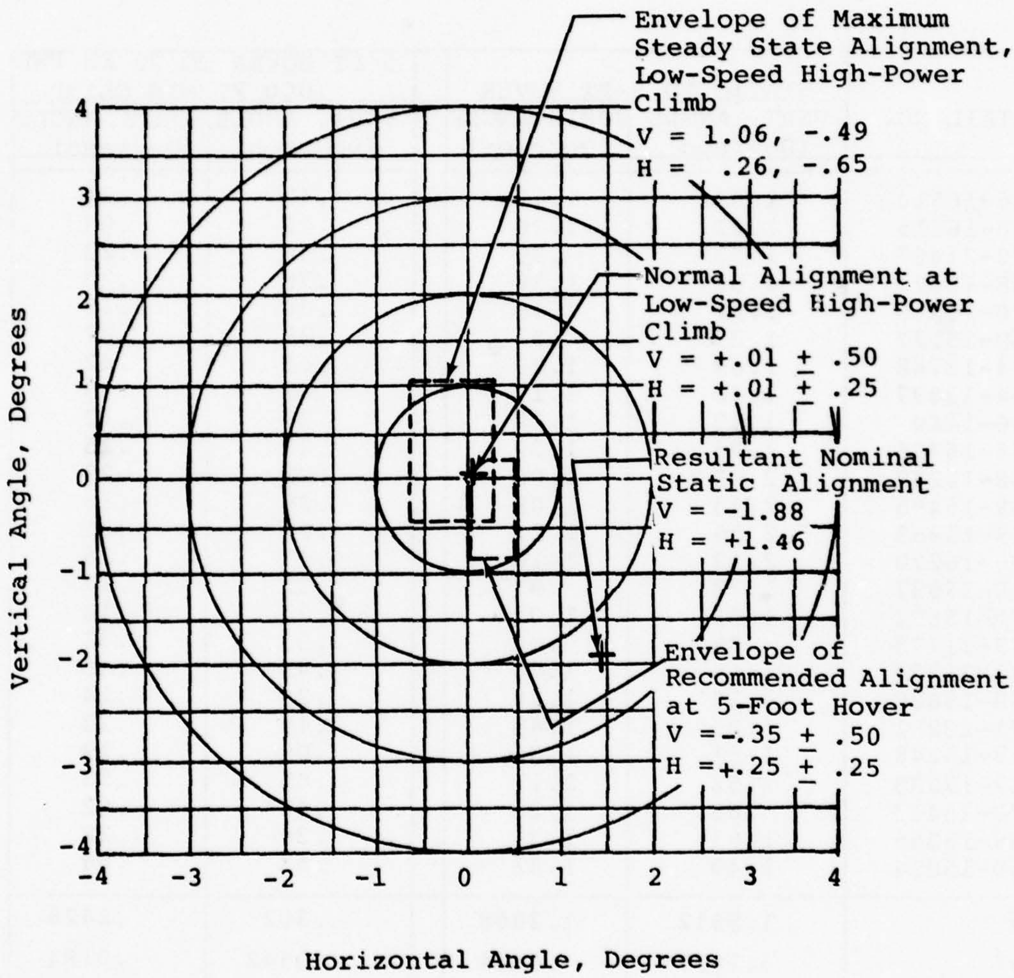


Figure 36. Improved Alignment Possible for Three Conditions and Maximum Expected Misalignment.

CONCLUSIONS

1. Dynamic drive shaft alignment measurement is more efficient, more accurate and more realistic than static shaft alignment measurement.

2. More UH-1 and AH-1 drive shaft alignments were found out of specific alignment (19) than within specified alignment (12).

3. UH-1 and AH-1 drive shaft alignment checks required 48 man-hours (two men for three days) when performed in accordance with TM 55-1520-210-20 (static alignment checks only).

4. UH-1 static and dynamic drive shaft alignment checks required 2 to 6 man-hours when performed with the drive shaft alignment indicator using the procedure of Appendix C.

5. Alignment change can be expedited through use of the data reported herein on shim change vs alignment change.

6. Textron Bulletin No. 205-76-9 is an improvement over TM 55-1520-210-20 alignment. Further improvement is possible.

7. Maximum operating misalignment of UH-1 drive shafts can be reduced from 4.96 degrees to 1.24 degrees for the worst high-power steady-state case measured, which was low-speed high-power climb.

RECOMMENDATIONS

1. Procure an evaluation quantity of drive shaft alignment indicator tools and undertake a program to reduce the high-power misalignment of UH-1 and AH-1 drive shafts.

2. Specify drive shaft alignment based on acceptable static alignment followed by measurement at 5-foot skid height hover.

3. Investigate the cost and benefits of replacing the present UH-1 engine-mount shim arrangement with a turnbuckle in each of two engine mount legs. The program should include design and analysis, followed by manufacture and test of several ship sets.

APPENDIX A

DRIVESHAFT ALIGNMENT PER TM55-1520-210-20

This appendix describes driveshaft alignment per Department of the Army Technical Manual TM55-1520-210-20, Organizational Maintenance Manual, Army Model UH-1D/H Helicopters, PP. 7-23-7-25 (Reference 2). The procedure was developed as part of the evaluation of the driveshaft alignment indicator tool.

Main driveshaft alignment is currently checked statically using a set of special mechanical tools. Prior to the check, four jacks and a depth micrometer are used to position and hold the soft-mounted transmission parallel to its supporting structure.

With the driveshaft removed, an extendable plug gage assembly is attached to the engine output. The plug gage serves to extend the rotational centerline of the engine output to a target plate mounted on the transmission input. An eccentrically located hole in the target plate will accept the plug gage if the vertical and lateral position of the transmission is correct. Nonparallelism of the rotational centerlines of the engine output and the transmission input is checked next, by attaching a dial indicator to the extendable plug gage assembly and trammelling the surface of the target plate which is perpendicular to the transmission input quill.

Main driveshaft alignment is altered by selectively shimming between one or more of the engine tubular mounts and the engine deck, thereby shifting the position of the engine.

TOOL SET T101419

ALIGNMENT PROCEDURE

	ALIGNMENT PROCEDURE
ACCESS TO SHAFT AREA	1- Open engine cowling and transmission fairing. (Figure A1) 2- Remove engine intake filters. (Figure A2) 3- Remove upper panel of induction baffle. (Figure A3) 4- Remove upper half of particle separator. (Figure A4) 5- Remove short shaft.
ACCESS TO PYLON AREA	6- Remove pylon soundproofing. 7- Remove lower access panels on both sides of pylon. (Figure A1) 8- Remove upper access panels on both sides of pylon. (Figure A1)
LEVEL TRANSMISSION	9- Mount maintenance hoist on helicopter. (Figure A5) 10- Attach hoisting clevis to top of mast nut. 11- Remove nut and washer from lift link lower bolt. (Figure A6) 12- Hoist transmission to unload lift link bolt. 13- Install A4 leveling jacks. (Figure A6) 14- Adjust jacks so that transmission is parallel to supporting structure.

TOOL SET T101419

ALIGNMENT PROCEDURE

	ALIGNMENT PROCEDURE
INSTALL TOOLING AND CALIBRATE	15- Adjust position of eccentric hole in target plate. (Figure A7) 16- Secure target plate to transmission curvic coupling. (Figure A7) 17- Secure gage pin assembly to engine curvic coupling. (Figure A7)
CHECK ALIGNMENT	18- Push plunger of gage pin assembly forward toward target plate. (Figure A7) 19- Largest diameter of plunger should enter target hole. If not, note amount and location of interference. 20- Mount dial indicator on plunger so that tip contacts target plate. (Figure A7) 21- Rotate dial indicator at least one turn and stop at point of greatest reading. This should occur between 8 and 10 o'clock positions on target plate. "Zero" the indicator. 22- Rotate "zeroed" indicator another turn and check total indicator reading. Should not exceed .016 inch. NOTE Assume misalignment is incorrect and engine must be shimmed.
SHIM ENGINE	23- Loosen screws around intake bellmouth in forward firewall and around attachment ring in rear fire-wall. (Figures A8 and A9) 24- Consult Figure A7 to determine where shim stack must be altered. Make shim change.

ALIGNMENT PROCEDURE

	ALIGNMENT PROCEDURE
RECHECK ALIGNMENT	25- Push plunger of gage pin assembly forward toward target plate. Largest diameter of plunger should enter target hole. 26- Rotate dial indicator at least one turn and stop at point of greatest reading. This should occur between 8 and 10 o'clock positions. "Zero" the indicator. 27- Rotate "zeroed" indicator another turn and check T.I.R. Should not exceed .016 inch. NOTE Assume alignment is correct at this point.
RE-MOVE TOOL-ING	28- Remove alignment tool set, leveling jacks, and maintenance hoist.
SECURE AIRCRAFT	29- Retighten screws in firewalls. 30- Install nut, washer, and cotter pin on lower bolt of lift link. 31- Install short shaft. 32- Install upper half of particle separator. 33- Install upper panel of induction baffle. 34- Install engine intake filters. 35- Close engine cowling and transmission fairing.

TOOL SET T101419

ALIGNMENT PROCEDURE

	ALIGNMENT PROCEDURE
SECURE AIRCRAFT	36- Close upper access panels on both sides of pylon. 37- Close lower access panels on both sides of pylon. 38- Install soundproofing. END

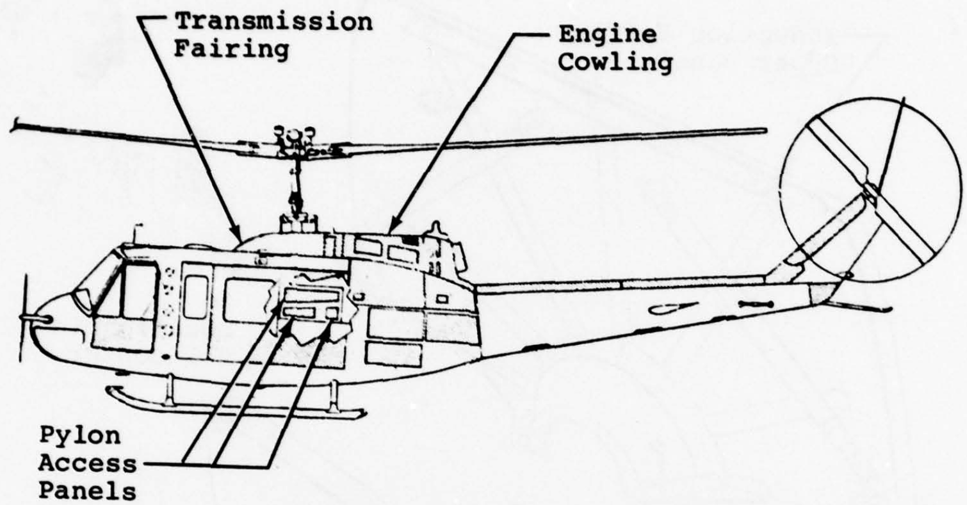


Figure A1. Fairing, Cowling, and Access Panels.

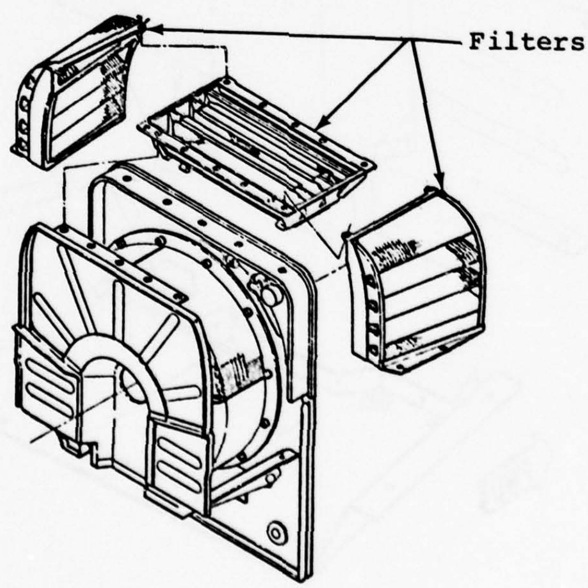


Figure A2. Engine Air Intake Filters.

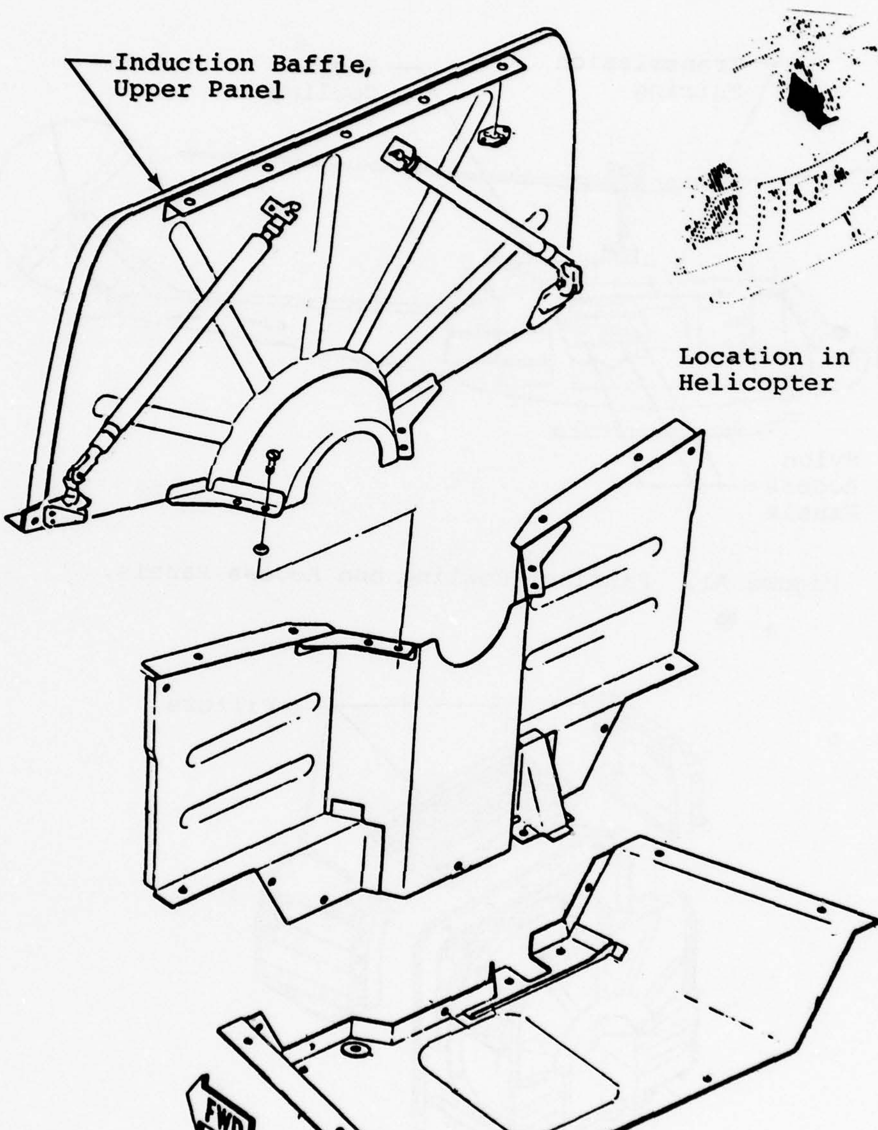


Figure A3. Induction Baffle Installation.

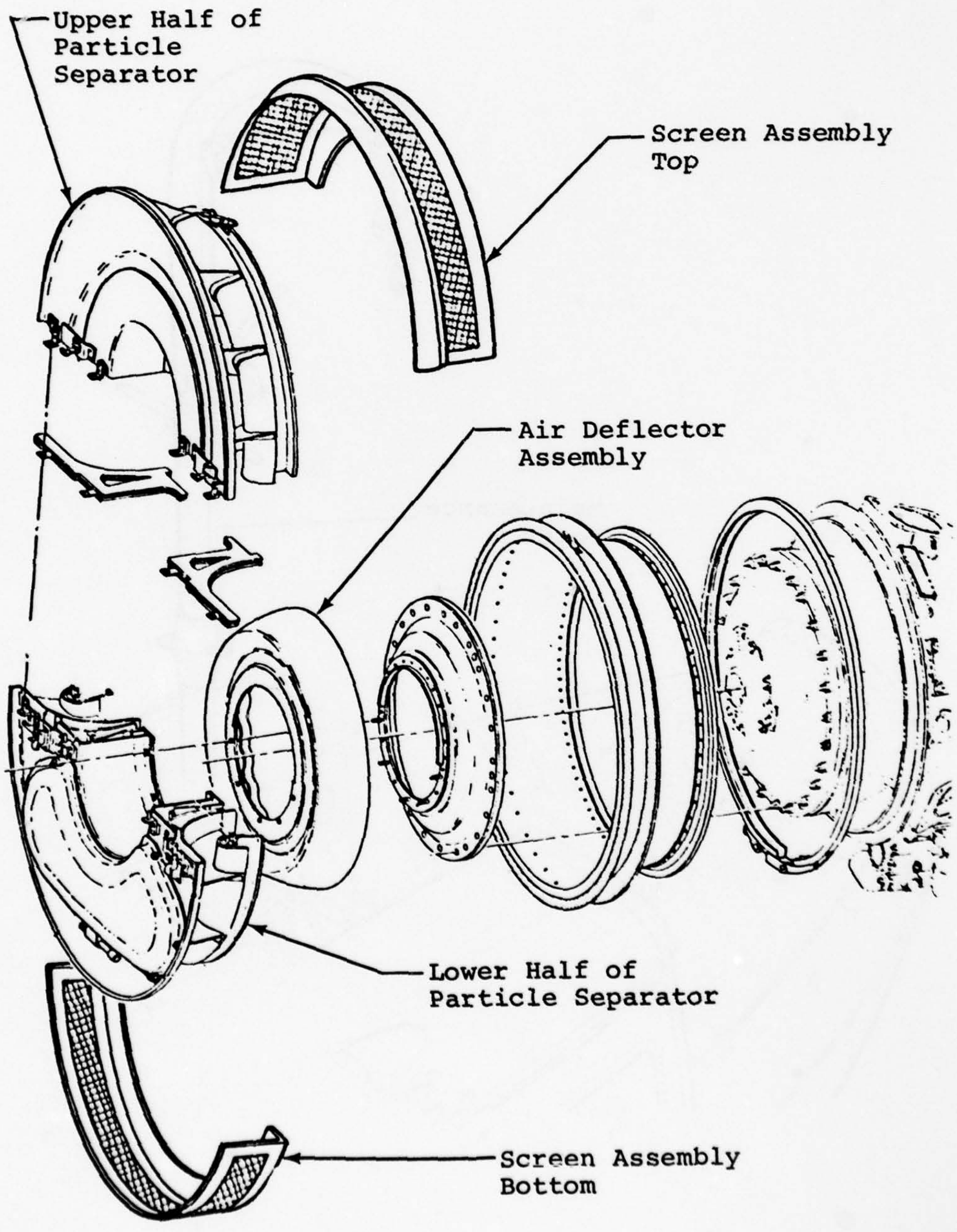


Figure A4. Particle Separator, Self-Purging Type.

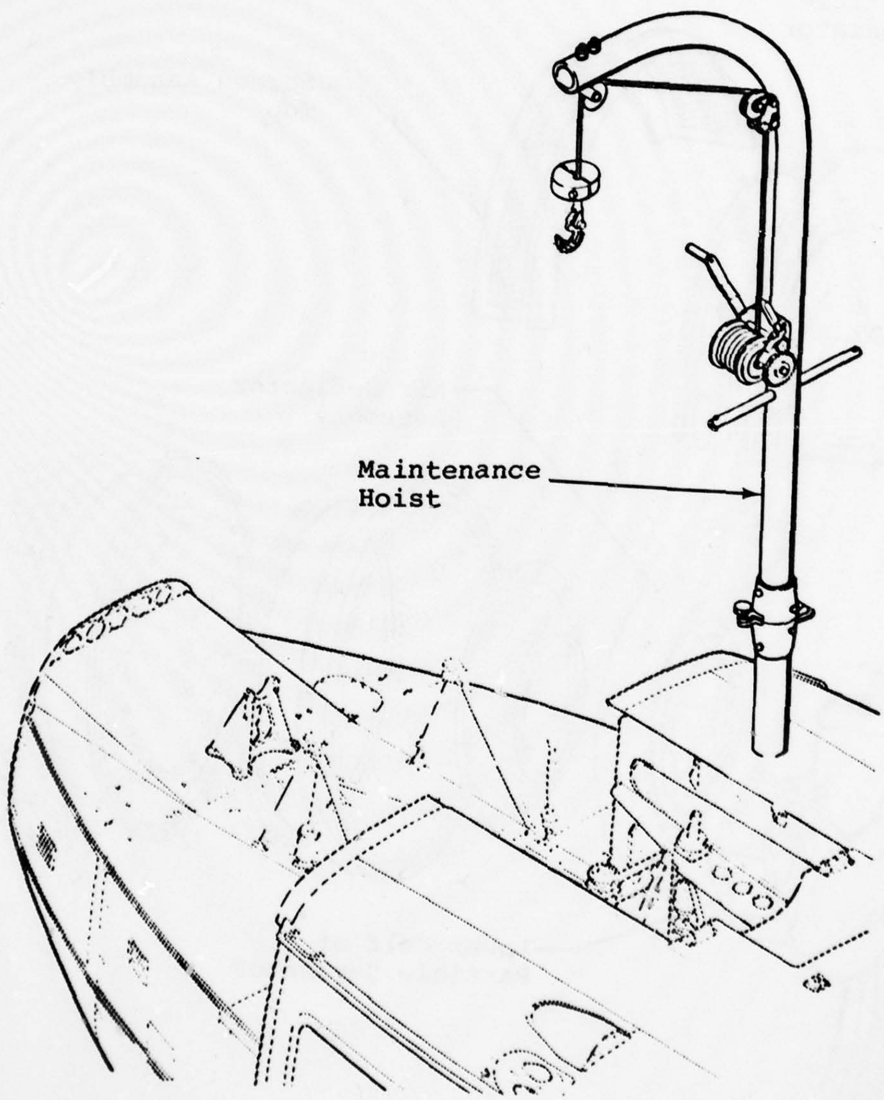


Figure A5. Maintenance Hoist.

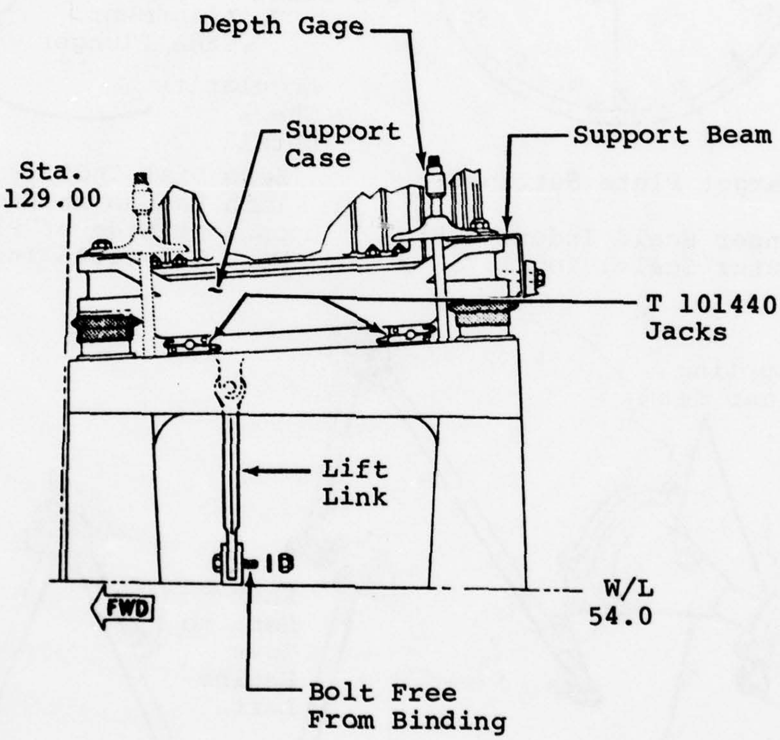


Figure A6. Leveling Main Transmission.

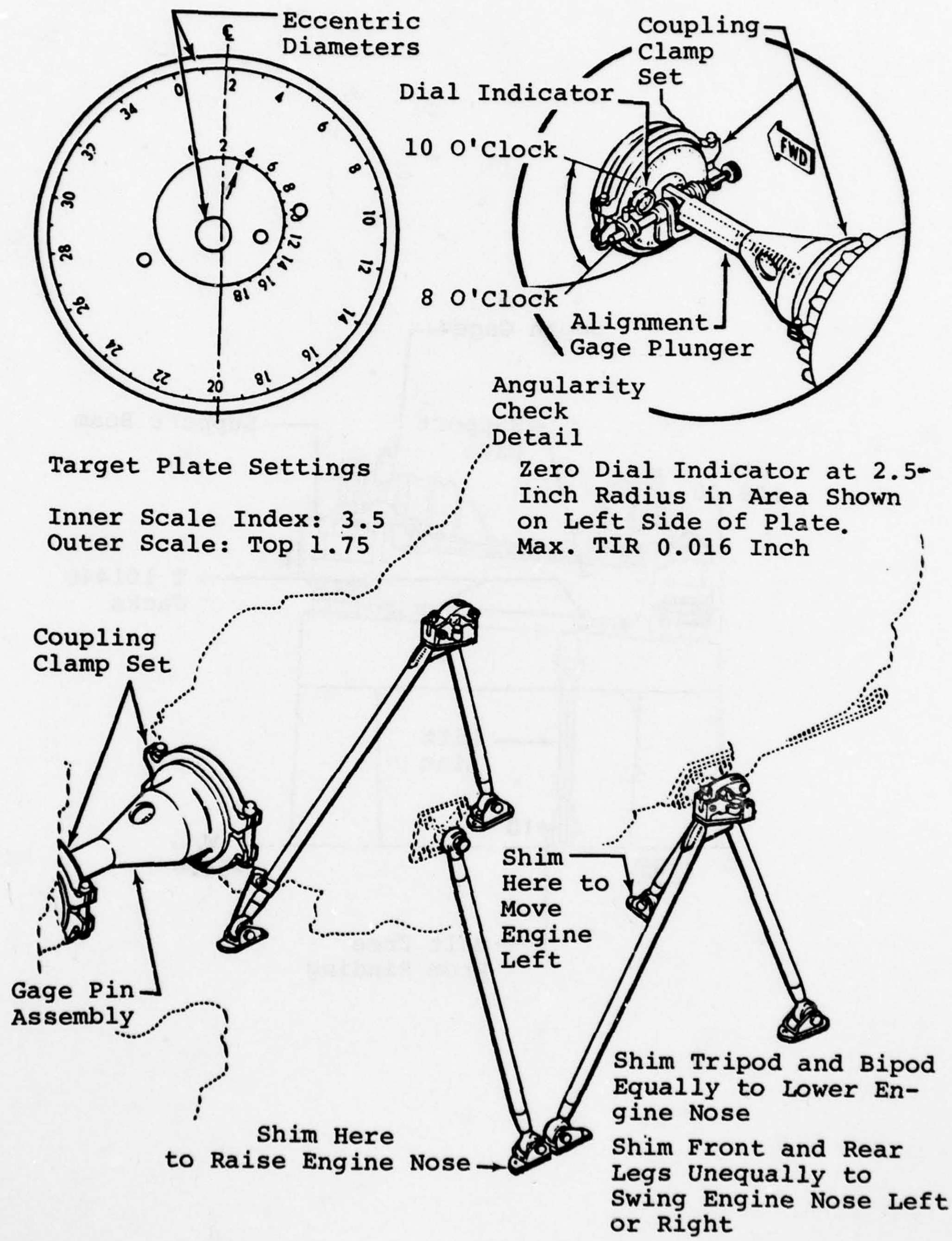


Figure A7. Use of Existing Alignment Tool Set.

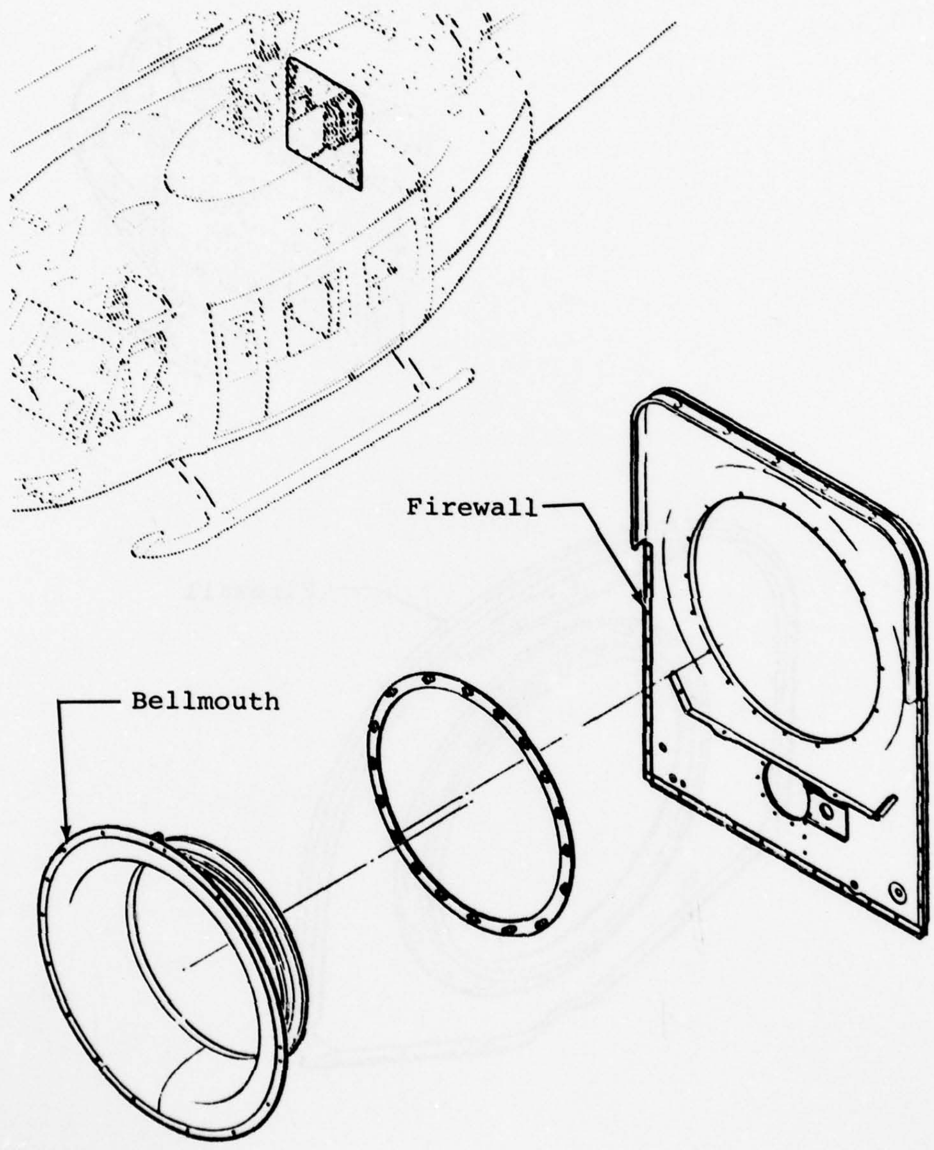


Figure A8. Forward Firewall and Bellmouth Assembly.

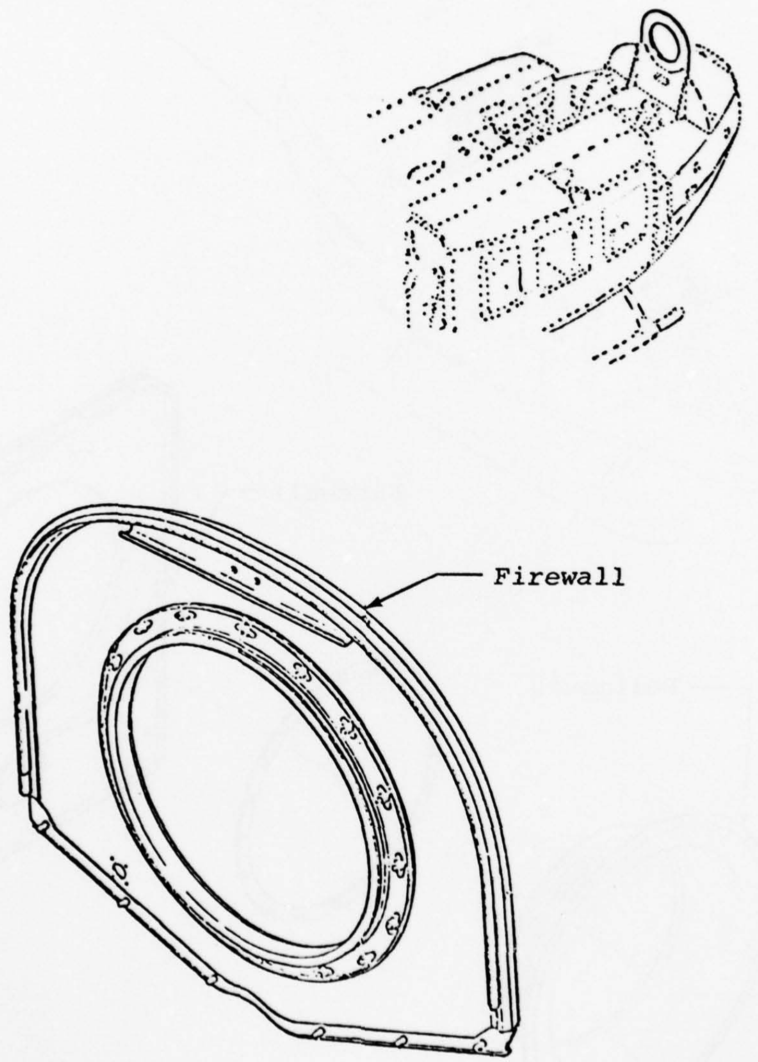


Figure A9. Aft Firewall.

APPENDIX B

BELL HELICOPTER COMPANY SERVICE BULLETIN NO. 205-75-9

This service bulletin changes the static driveshaft alignment. One purpose of this program was to evaluate the effect of the changes made by this service bulletin. The procedure described in Appendix A is retained.

SERVICE BULLETIN

BELL HELICOPTER COMPANY
POST OFFICE BOX 482 · FORT WORTH TEXAS 76101 · A TEXTRON COMPANY

NO. 205-76-9
DATE 9-9-76
PAGE NO. 1 of 3

DATE	
REV.	

SERVICE APPROVAL	ENGINEERING APPROVAL	FAA/DER APPROVAL
H. Ostrizek	[illegible]	[illegible]

SUBJECT: ENGINE TO TRANSMISSION DRIVE SHAFT ALIGNMENT.

REASON: To provide improved gear patterns.

HELICOPTERS AFFECTED: 205A-1 Helicopters S/N 30001 thru 30232
205A-1 Helicopters S/N 30233 and subsequent will have these changes accomplished prior to delivery.

WEIGHT CHANGE: Not applicable.

ACCOMPLISHMENT:

(A) Helicopters actively engaged in transportation of external cargo - no later than the next thirty (30) hours of operation or within ten (10) days after receipt of this bulletin, whichever occurs first.

(B) Helicopters in standard passenger configuration and not engaged in transportation of external cargo - at next convenient scheduled maintenance period or engine change but no later than the next scheduled airframe overhaul inspection.

DESCRIPTION:

1. Remove the main drive shaft assembly in accordance with the appropriate Maintenance Manual.

2. Align the engine to transmission drive shaft in accordance with the appropriate Maintenance Manual using the following target plate settings and tolerances:

NOTE

For ease of leveling transmission, disconnect 5th mount assembly.

A. Index the target plate inner scale to 8.0 (instead of 3.5).

B. Index the target plate outer scale to 35.6 (instead of 1.75).

C. When checking angularity zero dial indicator at 2.5 inch radius at 12 o'clock position. Read + .030 ± .004 at 6 o'clock. Re-zero indicator at the 3 o'clock position. Read + .006 ± at .004 at 9 o'clock.

NOTE

Plus indicator reading means that flange on transmission is closer to flange of the engine.

3. If the total laminated shim thickness (P/N 205-060-137-1 or 205-060-138-1) under any engine support fittings exceeds .188 inches, fabricate a plate of 2024-T4 aluminum alloy .100 inch thick, same outside dimensions as shim stock. Structurally bond the plate to the engine service deck with EC934. Total thickness of shims and plate under any engine mount fitting must not exceed .288 inches.

NOTE

Check engine deck fitting screws and bolts for proper length and thread engagement.

4. Reinstall the drive shaft assembly in accordance with the appropriate maintenance manual.

5. Check drive shaft alignment whenever one or more of the following conditions exists.

A. Excessive wear of the coupling spline.

B. Indications of excessive heating.

C. Replacement of the transmission isolation mounts.

D. Hard landings.

E. Replacement of the main transmission.

F. Replacement of the engine or engine mounts.

G. Major repair or replacement of components is required in center fuselages tail boom or pylon support structure.

H. Drive shaft misalignment is suspected for any reason.

6. <u>Parts Required</u>

Part Number	Nomenclature	Quantity
205-060-137-1	Shim	2
205-060-138-1	Shim	1

The material necessary to meet the requirements of this Service Bulletin must be procured from your usual Bell Helicopter Textron Spare parts source. Orders must include the ship-to address.

7. Information contained in this Service Bulletin will be incorporated into the next revision of the 205A-1 Maintenance Manual.

APPENDIX C

PROCEDURE FOR USING THE DRIVESHAFT ALIGNMENT INDICATOR

This procedure was developed as part of the evaluation of the driveshaft alignment indicator tool. Also, it is intended to be preliminary to an Aviation Unit Maintenance (AVUM) procedure.

Description of Driveshaft Alignment Indicator

The driveshaft alignment indicator installation is shown in Figures 2 and C1. Freely moving compressible struts are mounted to slightly amplify the misalignment angles imposed on the driveshaft couplings. The struts are mounted to structure by spherical self-aligning bearings. The bearings are located in target plates mounted on the transmission adapter plate and in target plates mounted on an A-frame attached to the engine particle separator. The struts are allowed to extend and compress freely to accommodate axial motions. The measuring devices are multi-vit noncontact electronic micrometers. The multi-vits are used to measure angular misalignment of the struts with respect to the transmission, and therefore the driveshaft. Measurement of angular misalignment of the engine-end coupling requires reversing the driveshaft indicator tool. The same mounting provisions accept the tool in either direction.

The alignment procedure is described and illustrated in preliminary AVUM form on the following pages. Photographs of components and of steps in the installation process are shown in Figures C9 through C23. The installation steps can be reversed for tool removal.

Note: Static and dynamic misalignment criteria are based on TM55-1520-210-20. Criteria based on this study would change Step 16 and Figure C6. On Figure C6, the safe envelope for hover at 5-foot skid height would be: vertical angle -1 degree to -3 degrees, horizontal angle 0.5 degree to 1.5 degrees. The acceptable alignment envelope on Figure C6 for hover at 5-foot skid height would be: vertical angle +.15 degree to -.65 degree, horizontal angle +.5 degree to 0 degree.

ALIGNMENT PROCEDURE

1- Open engine cowling and transmission fairing, Figure C2.

2- Remove engine intake filters, Figure C3.

3- Remove upper vertical panel of induction baffle, Figure C5.

4- Remove upper and lower halves of particle separator, Figure C4.

5- Remove lower vertical panel of induction baffle, Figure C5.

6- Install modified lower baffle assembly and lower half of particle separator.

7- Install transmission adapter on the transmission housing leaving an even amount of washers under each of the three mounting studs, Figure C1.

8- Install A-frame assembly on front of upper half of particle separator and reinstall on engine, Figure C1.

9- Place modified upper baffle assembly in position.

10- Insert horizontal angle strut assembly in position between the A-frame and the transmission adapter, Figure C1.

11- Insert vertical angle strut assembly in position between the A-frame and transmission adapter and secure modified upper baffle assembly, Figure C1.

12- Connect two electrical signal cables to the strut assemblies.

13- Secure demodulator power supply in aft cabin and connect electrical signal cable. Place indicator at observer's station and connect electrical signal cable.

14- Check the polarity of the aircraft wiring system and connect the power cable to the helicopter 28 VDC receptacle.

ALIGNMENT PROCEDURE

15- Switch power on, set selector switch to TRANS. Check for meter indication. If not OK, check for power available at receptacle. Check power cable.

16- Check static alignment for safe hover at 5-foot skid height: vertical angle +1 degree to -1 degree, horizontal angle +2.5 degrees to +.5 degree. Turn power off. If static alignment is not within limits, perform Steps 25 and 26, repeat Step 16.

17- Install engine intake filters.

18- Close engine cowling and transmission fairing.

19- With observer at his station, bring helicopter to 5-foot skid height hover.

20- Switch power on, check that selector switch is set to TRANS. Observe and record two meter readings.

21- Land helicopter and shut down engine.

22- Compare two readings with published requirements.

23- Plot the values for V and H on Figure C6. If the point falls anywhere within target area, alignment is acceptable per TM55-1520-210-20.

NOTE

Assume alignment is incorrect and engine must be shimmed.

24- Open engine cowling and transmission fairing.

25- Loosen screws around intake bellmouth in forward firewall and around attachment ring in aft firewall, Figures C7 and C8.

26- Consult Figure C6 to determine amount and location of shim change required. Make shim change. After shim change tighten screws around intake bellmouth and in aft firewall.

27- Close engine cowling and transmission fairing.

ALIGNMENT PROCEDURE

28- With observer at his station, bring helicopter to 5-foot skid height hover.

29- Switch power on. Observe and record two meter readings.

30- Land helicopter and shut down engine.

31- Plot values for V and H on Figure C6.

NOTE

Assume alignment is correct at this point.

32- Open engine cowling and transmission fairing.

33- Remove engine intake filters.

34- Remove modified upper panel of induction baffle and remove link assemblies and electric cables.

35- Remove particle separator and A-frame and transmission adapter.

36- Install original upper and lower panels of induction baffle.

37- Install particle separator.

38- Install engine intake filters.

39- Close engine cowling and transmission fairing.

END

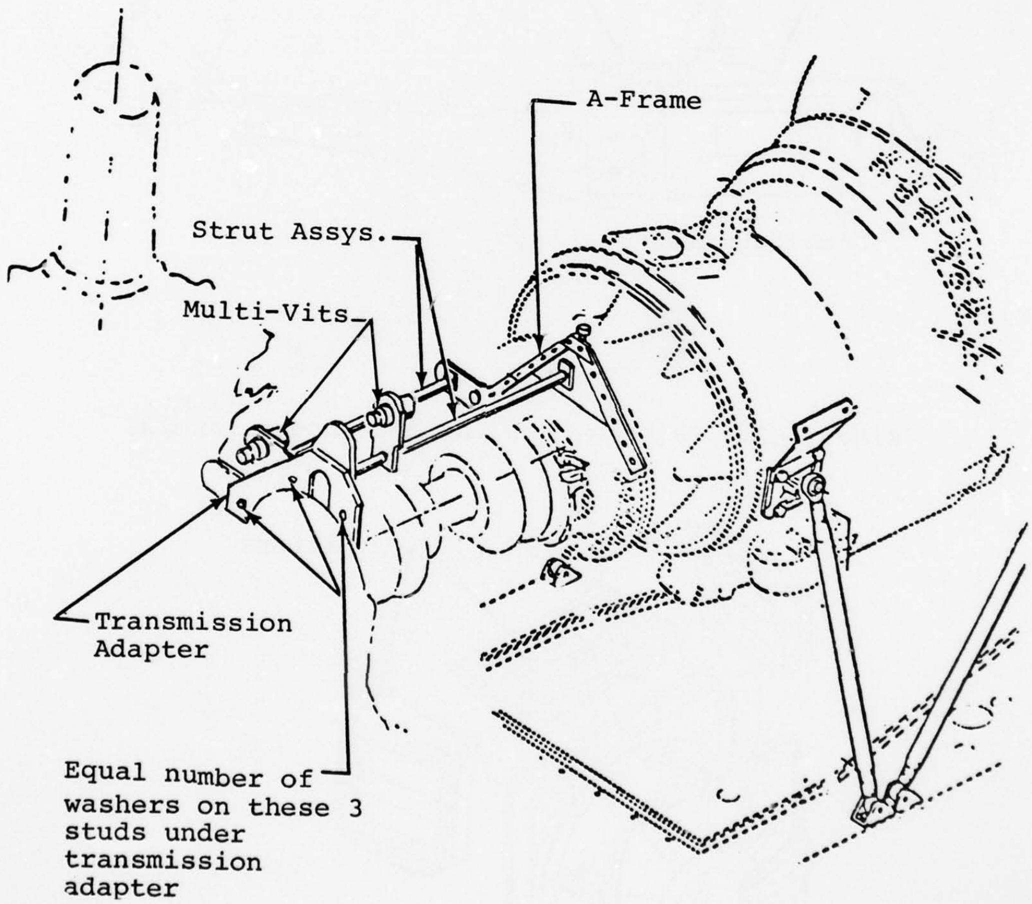
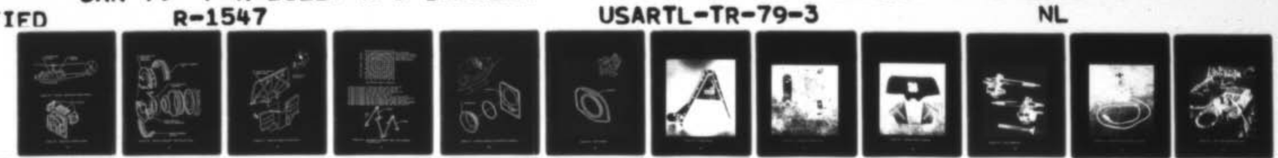


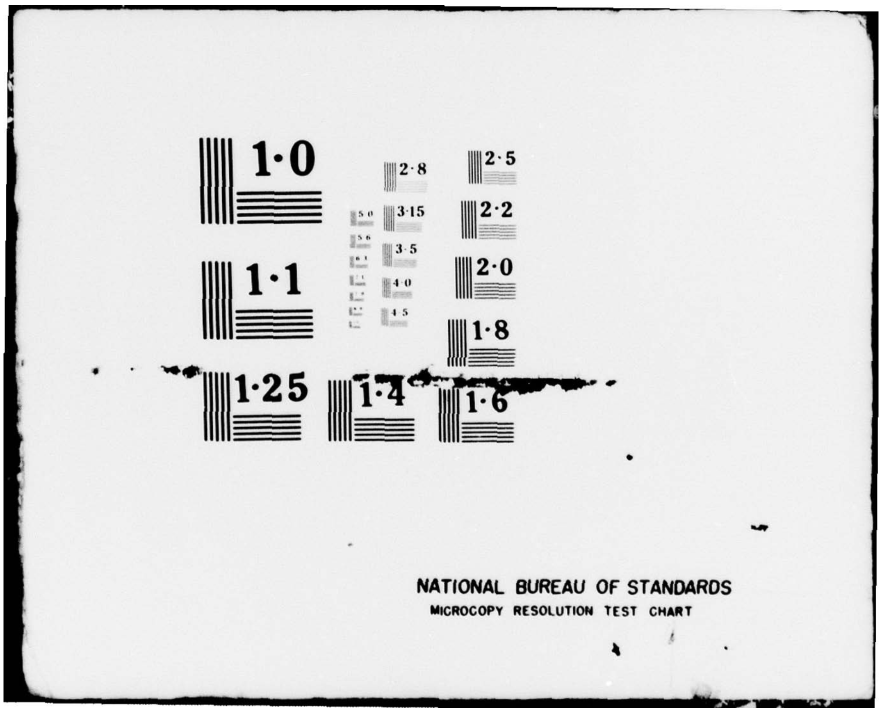
Figure C1. Driveshaft Alignment Indicator Installation.

AD-A065 988 KAMAN AEROSPACE CORP BLOOMFIELD CONN F/G 1/3
DRIVESHAFT ALIGNMENT INDICATOR.(U)
JAN 79 F A BILL, R B BOSSLER DAAJ02-77-C-0006
UNCLASSIFIED R-1547 USARTL-TR-79-3 NL

2 OF 2
ADA
065988



END
DATE
FILMED
5-79
DDC


1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0
4·5
5·0
5·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

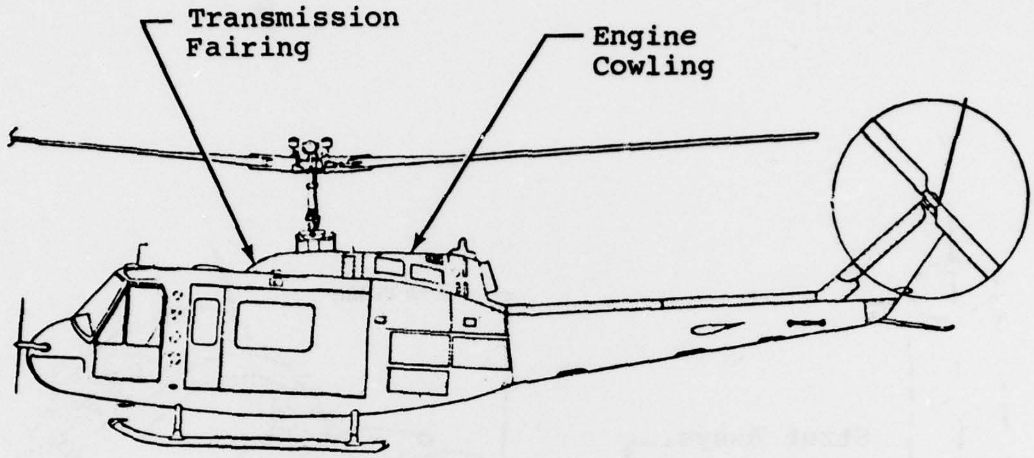


Figure C2. Fairing, Cowling, and Access Panels.

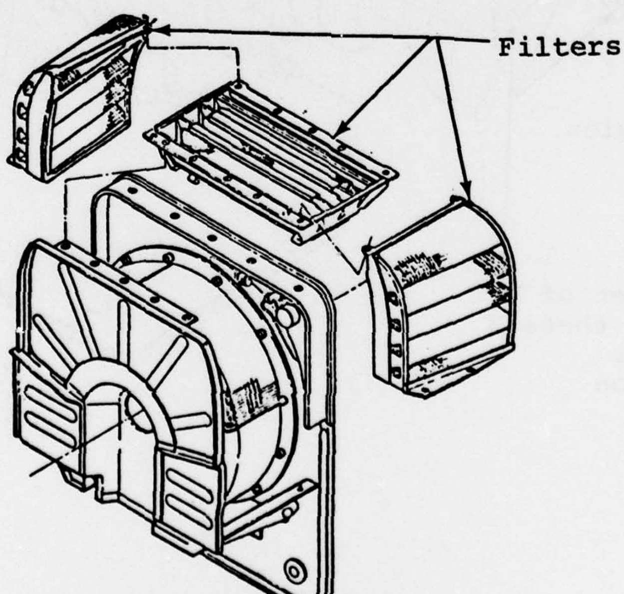


Figure C3. Engine Air Intake Filters.

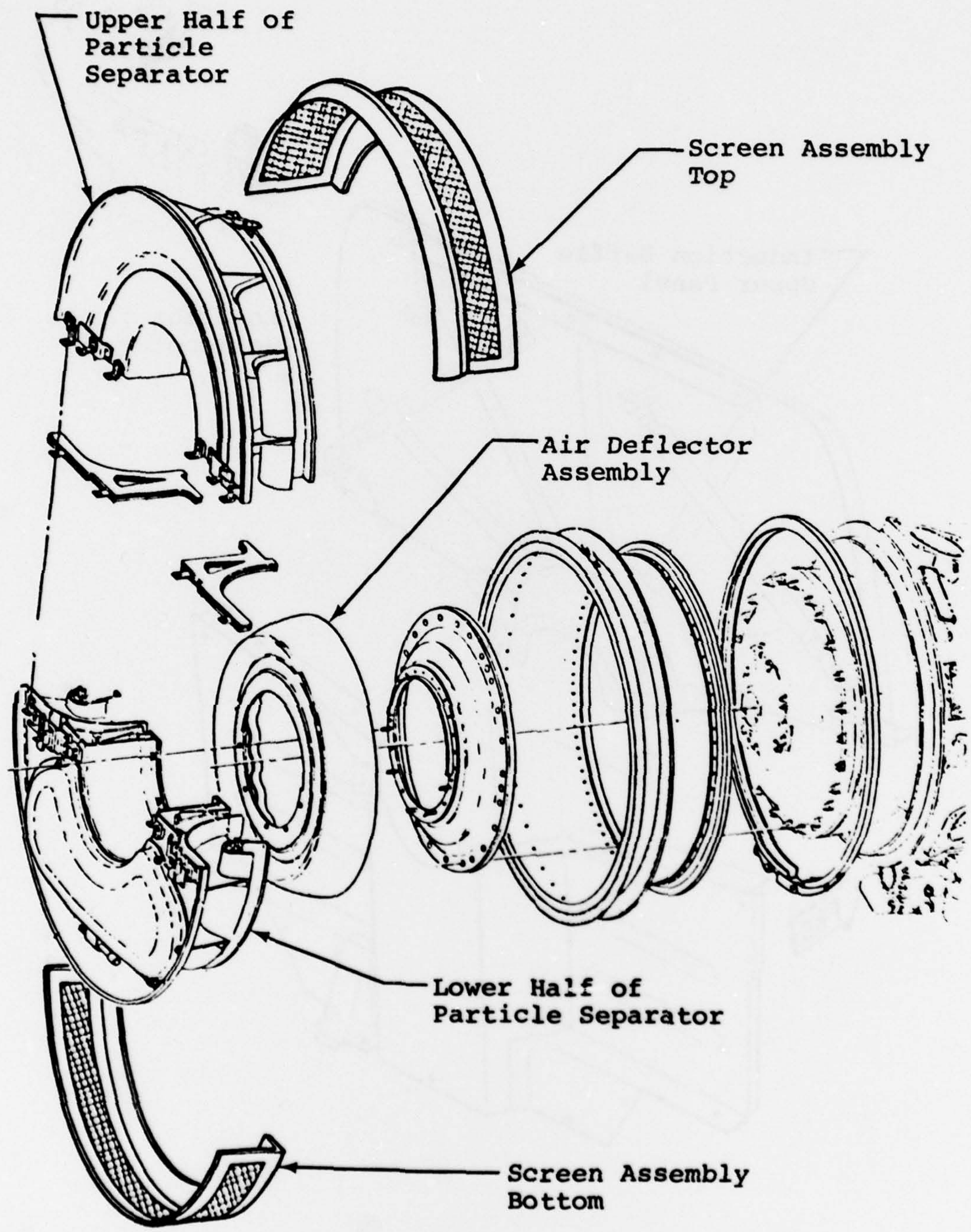


Figure C4. Particle Separator, Self-Purging Type.

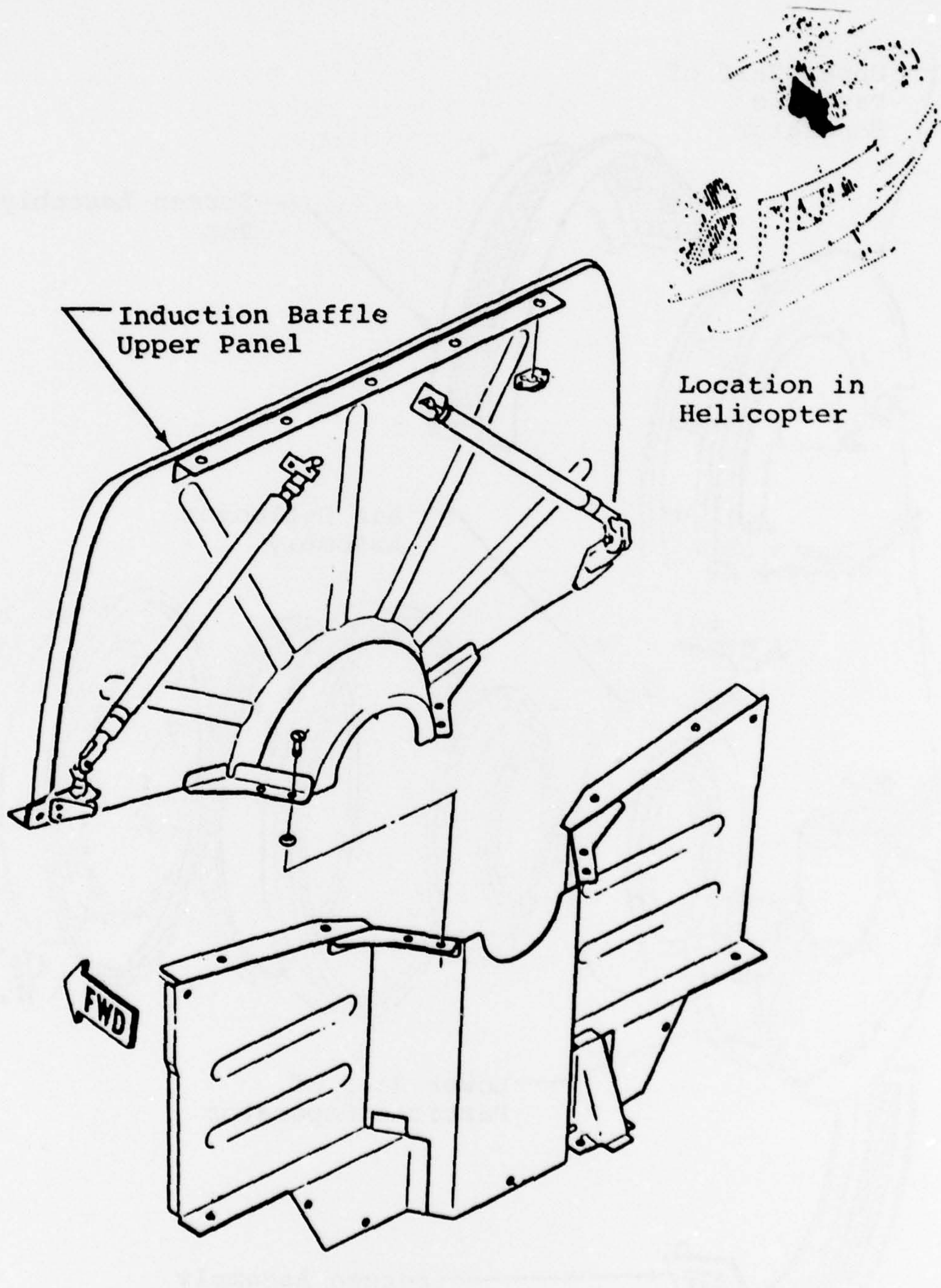
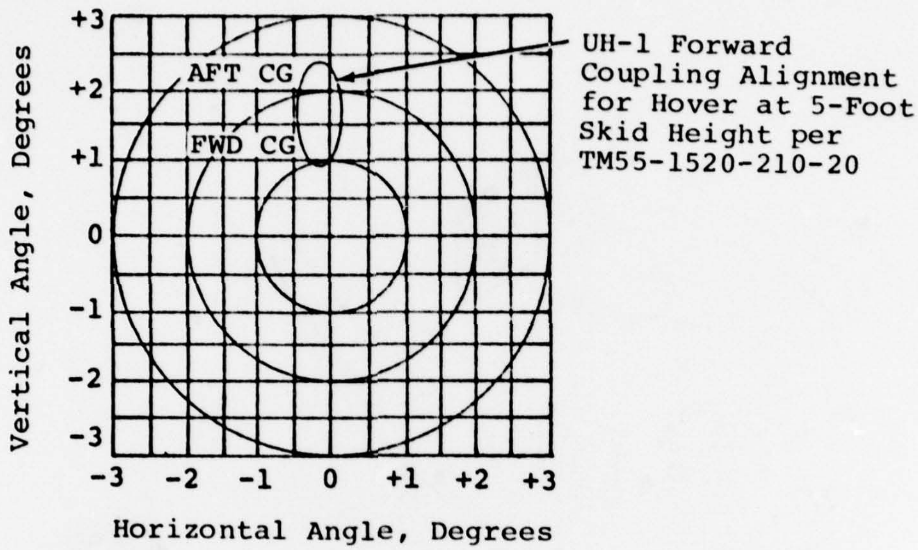


Figure C5. Induction Baffle Installation.



To move 1/2 degree to the left, remove .075" from Leg "A".
To move 1/2 degree to the right, add .075" to Leg "A".
To move 1/2 degree to the left, add .063" to Leg "E".
To move 1/2 degree to the right, remove .063" from Leg "E".
To move 1/2 degree up, remove .029" from Leg "F".
To move 1/2 degree down, add .029" to Leg "F".
To move 1/2 degree up and 1/2 degree right, add .038" to Leg "B".
To move 1/2 degree down and 1/2 degree left, remove .038" from Leg "B".
To move 1/2 degree left and 1/4 degree up, add .058" to Leg "C".
To move 1/2 degree right and 1/4 degree down, remove .058" from Leg "C".
To move 1/2 degree left and 1/4 degree down, remove .045" from Leg "D".
To move 1/2 degree right and 1/4 degree up, add .045" to Leg "D".

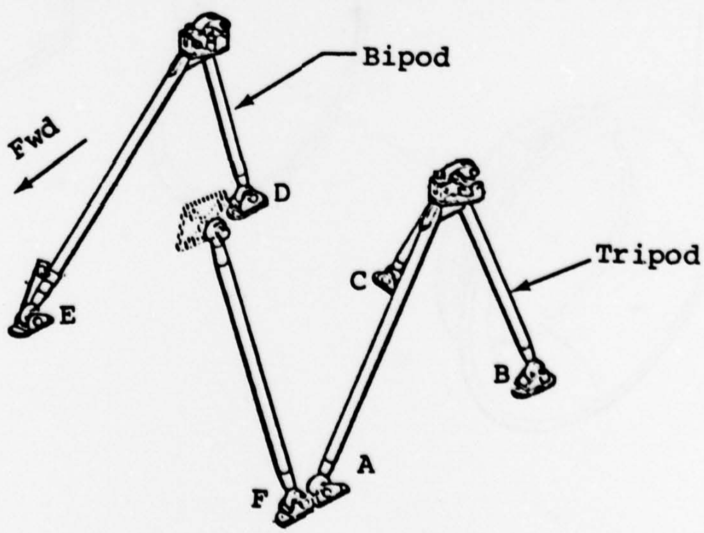


Figure C6. Driveshaft Alignment Chart with Shimming Instructions.

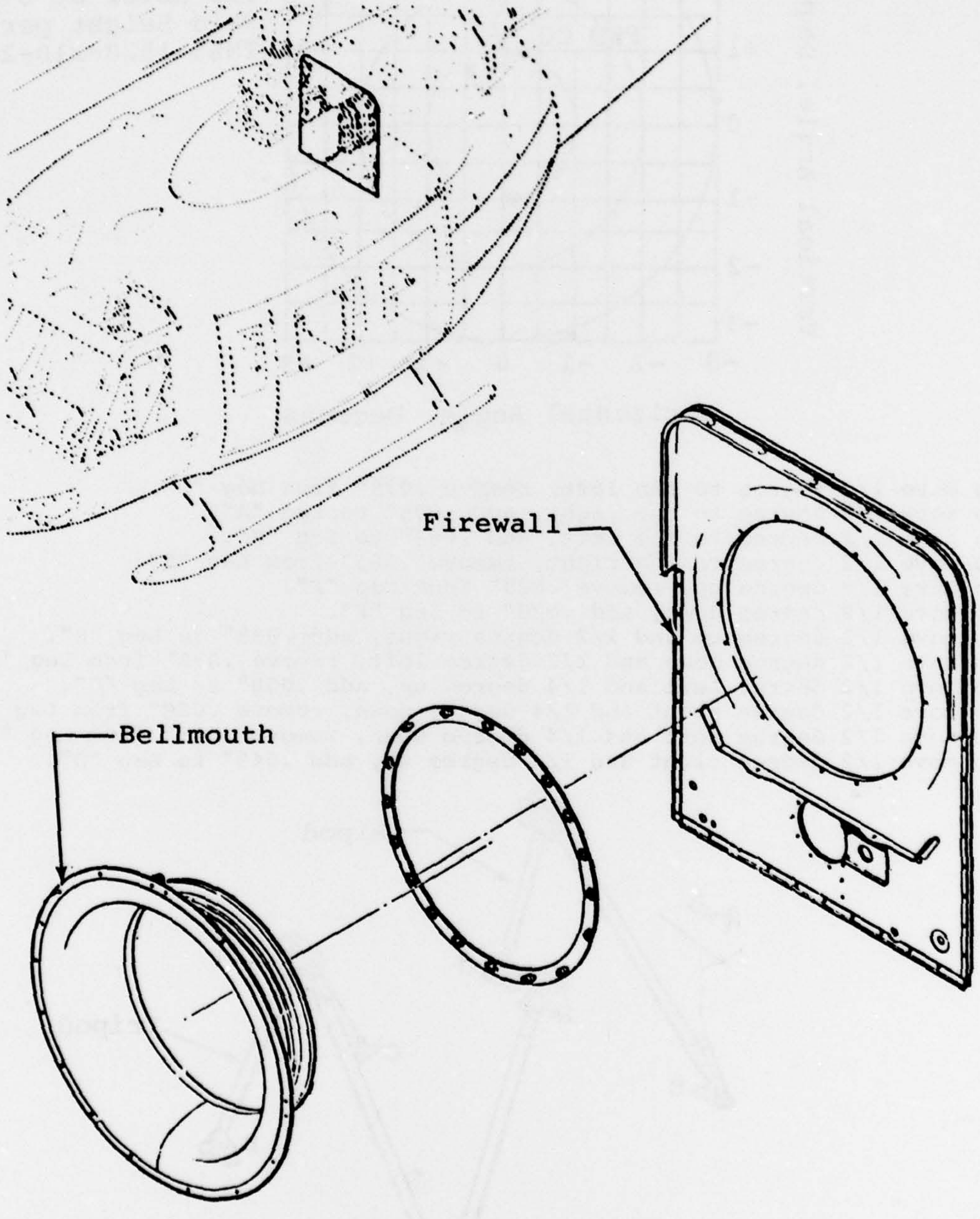


Figure C7. Forward Firewall and Bellmouth Assembly.

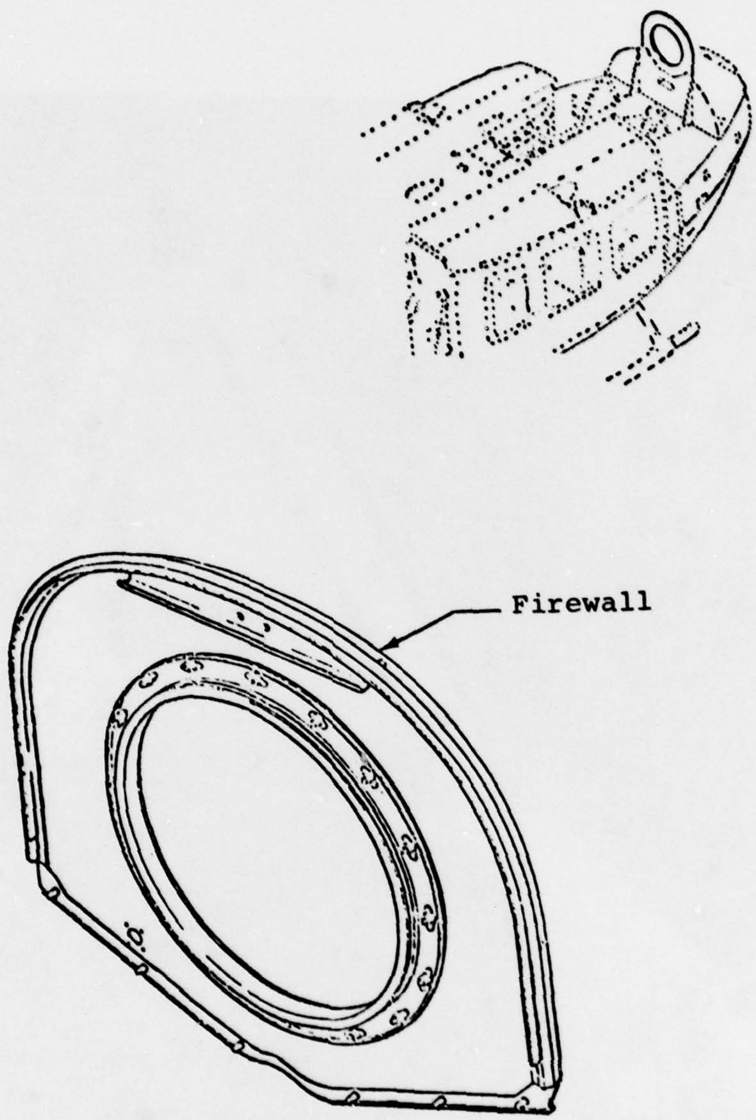


Figure C8. Aft Firewall.

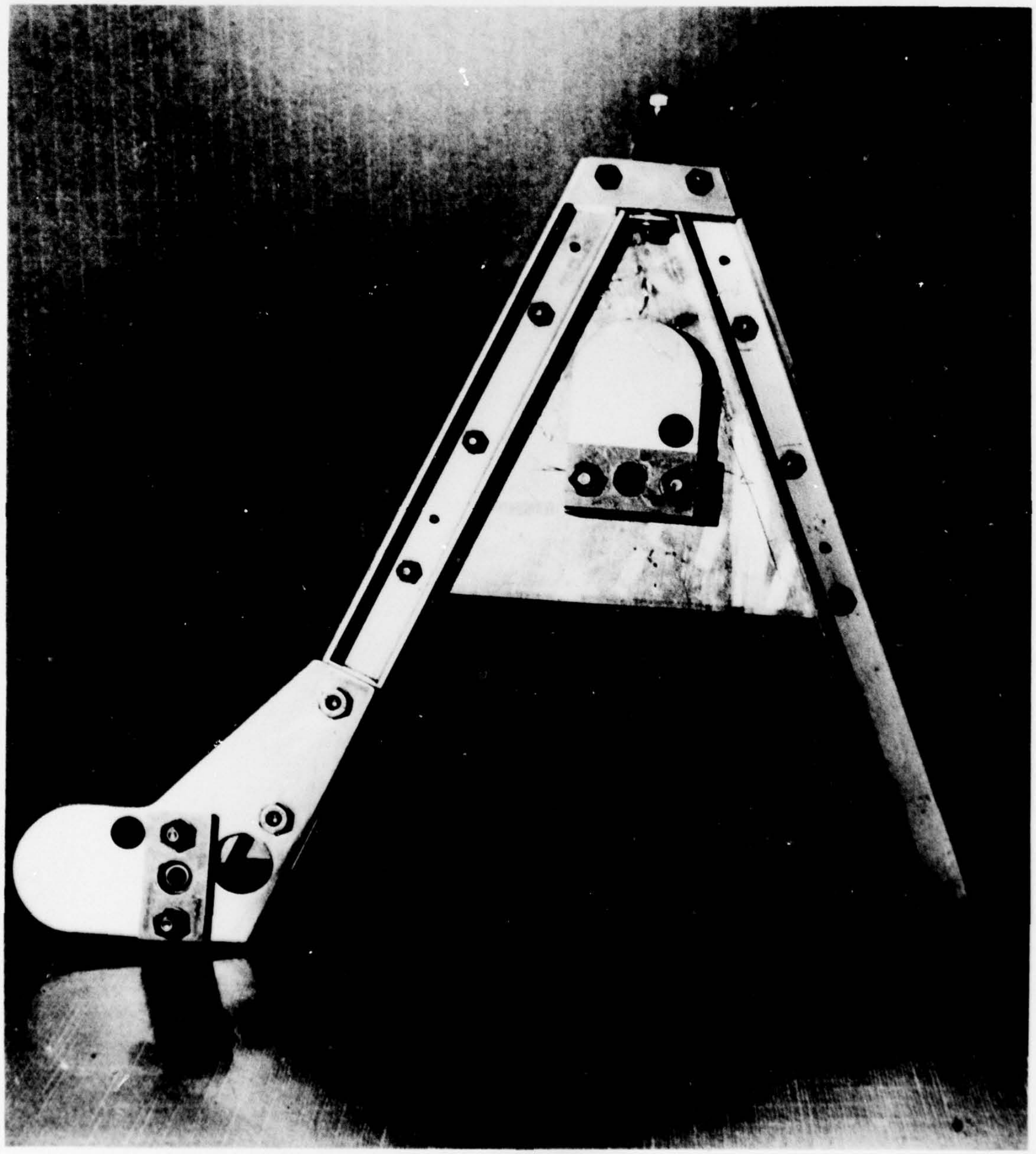


Figure C9. A-Frame Mount.

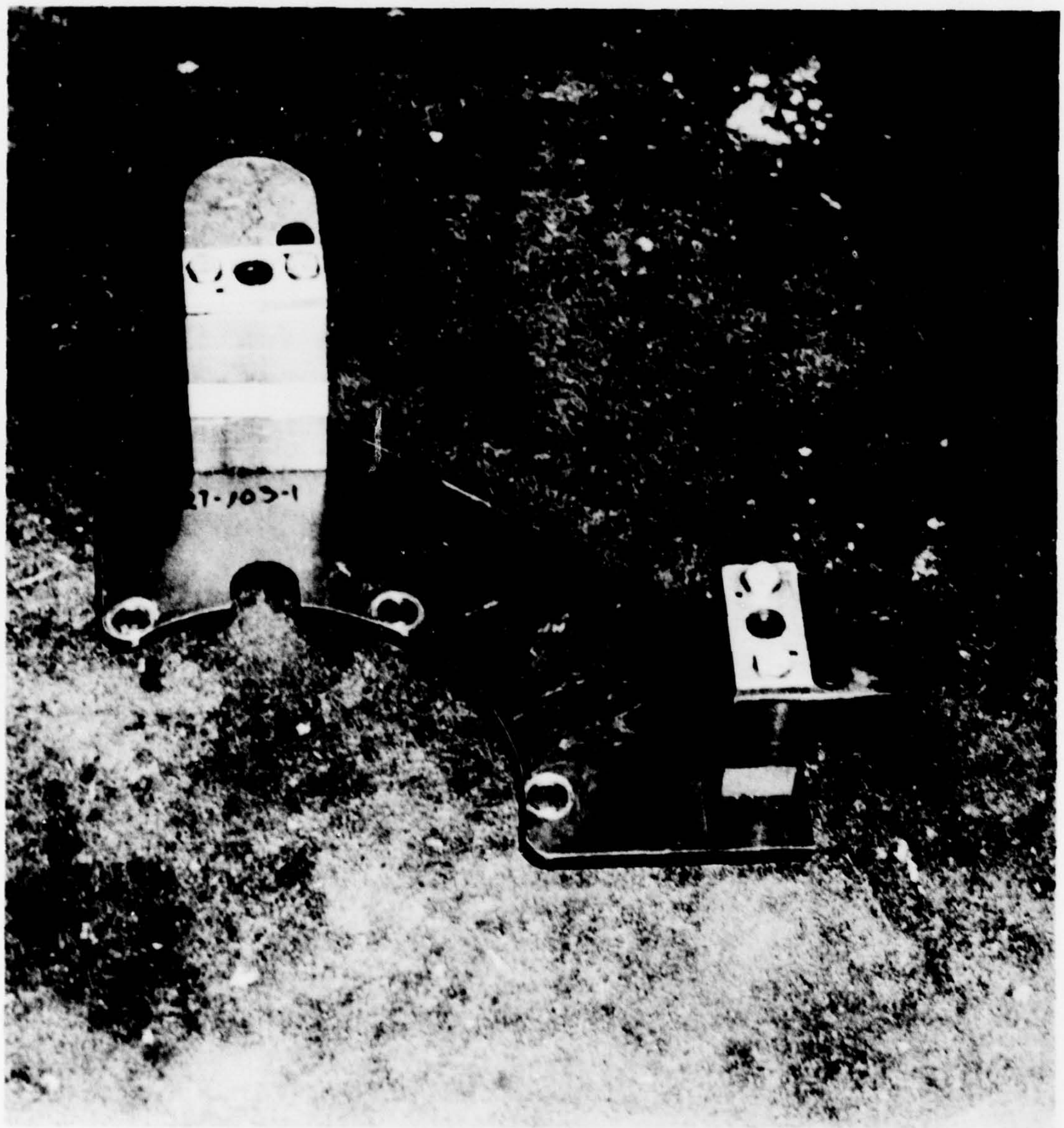


Figure C10. Transmission Mount Plate.

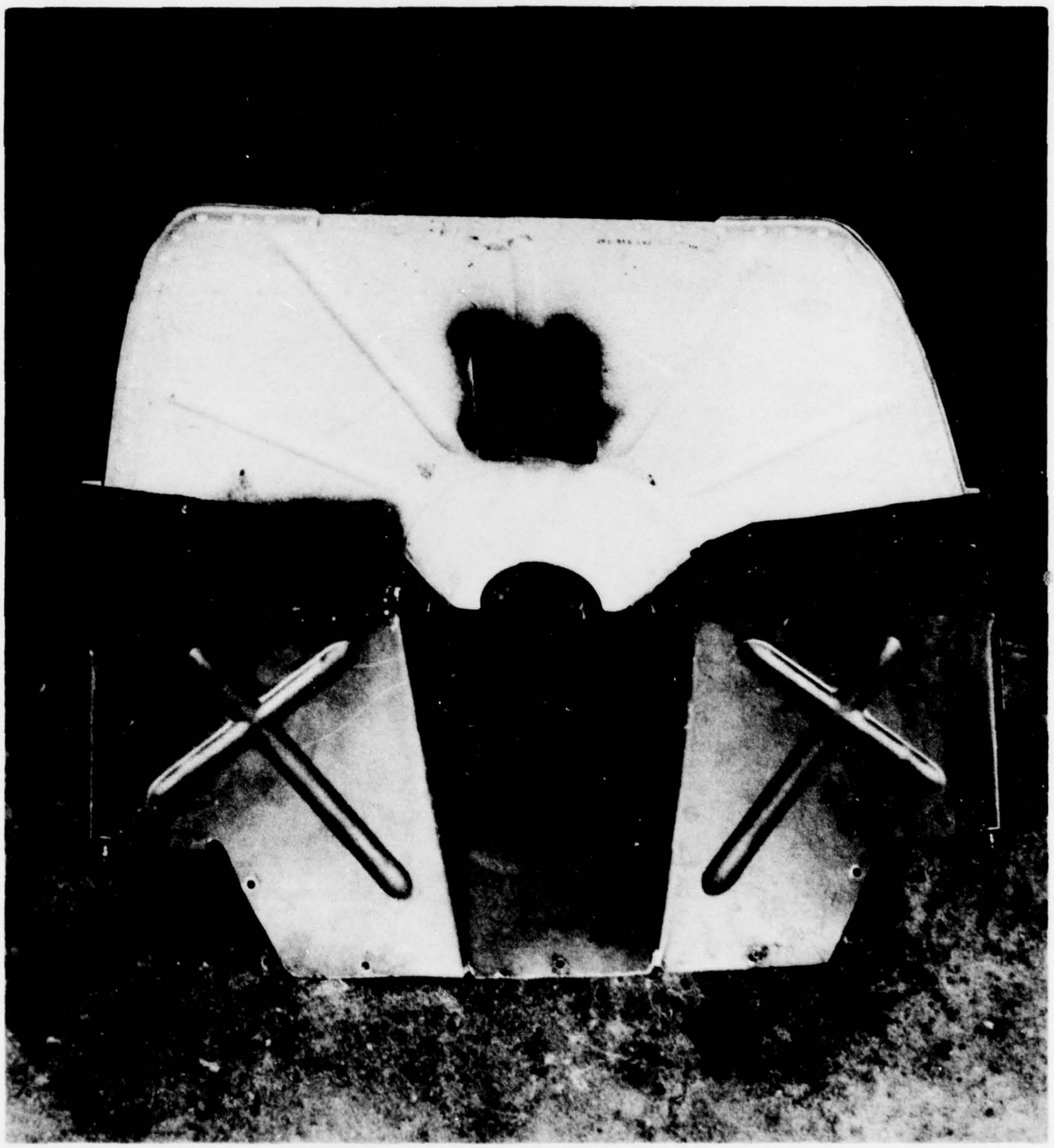


Figure C11. Modified Baffle Assembly.

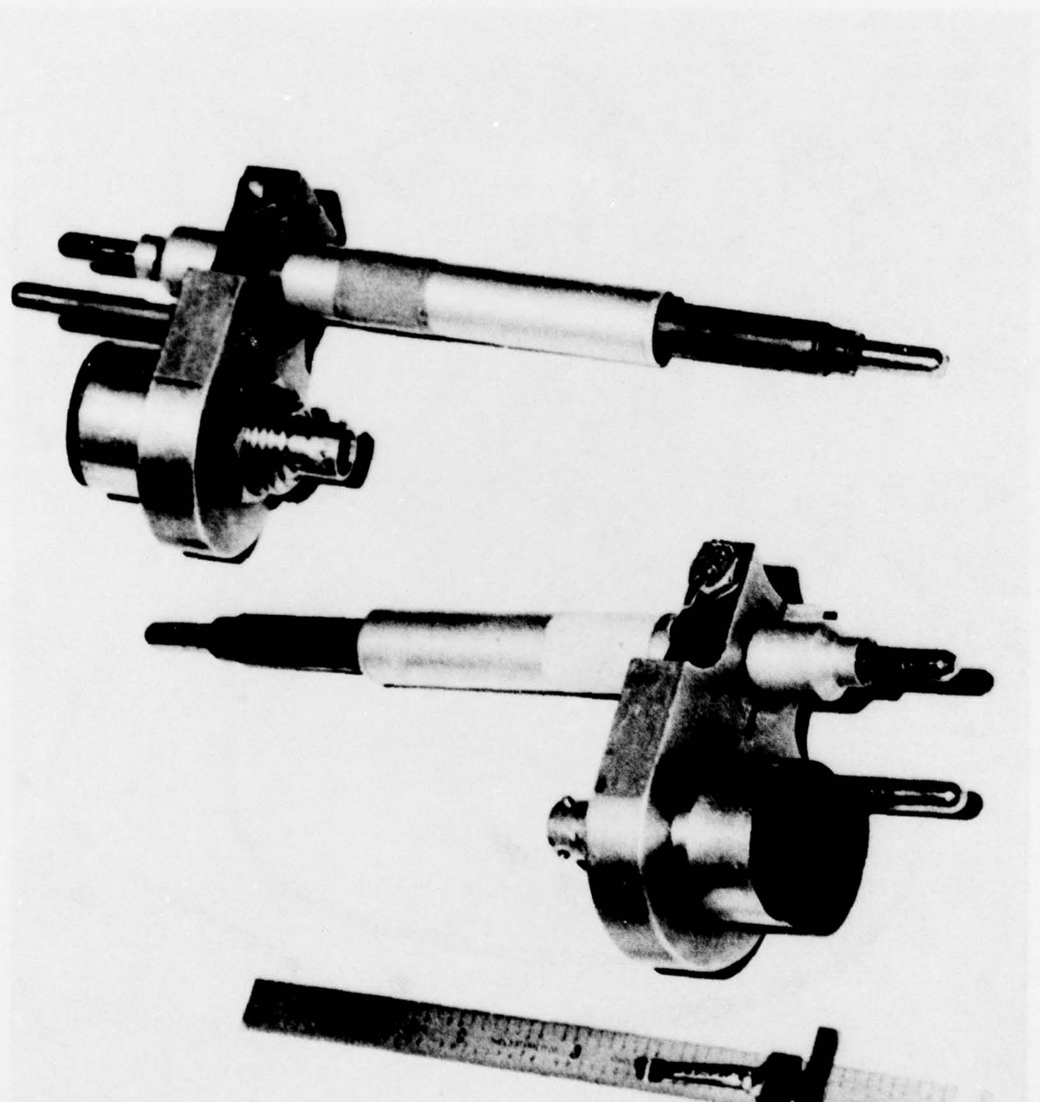


Figure C12. Strut Assemblies.

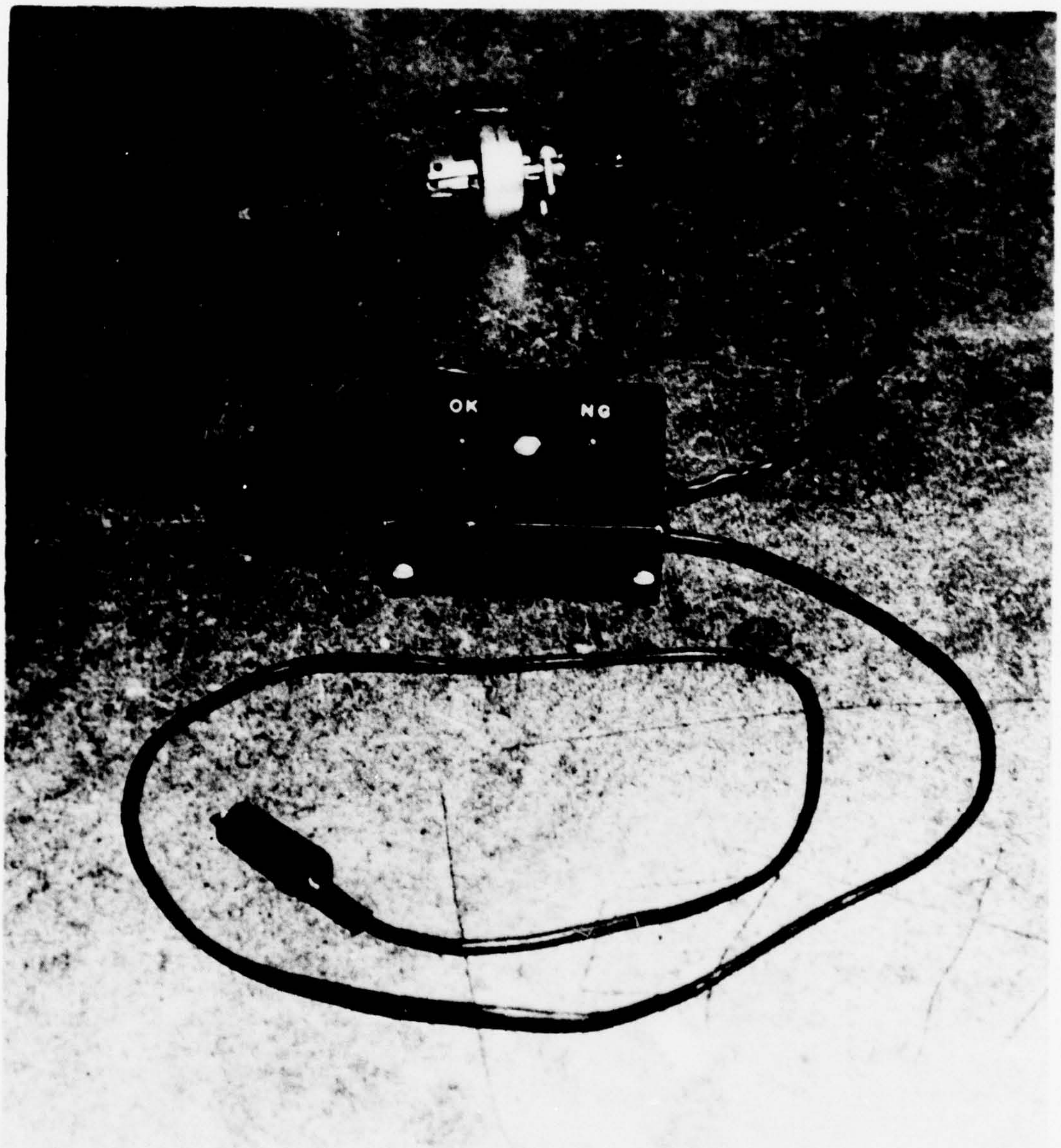


Figure C13. Helicopter Wiring Polarity Checker.

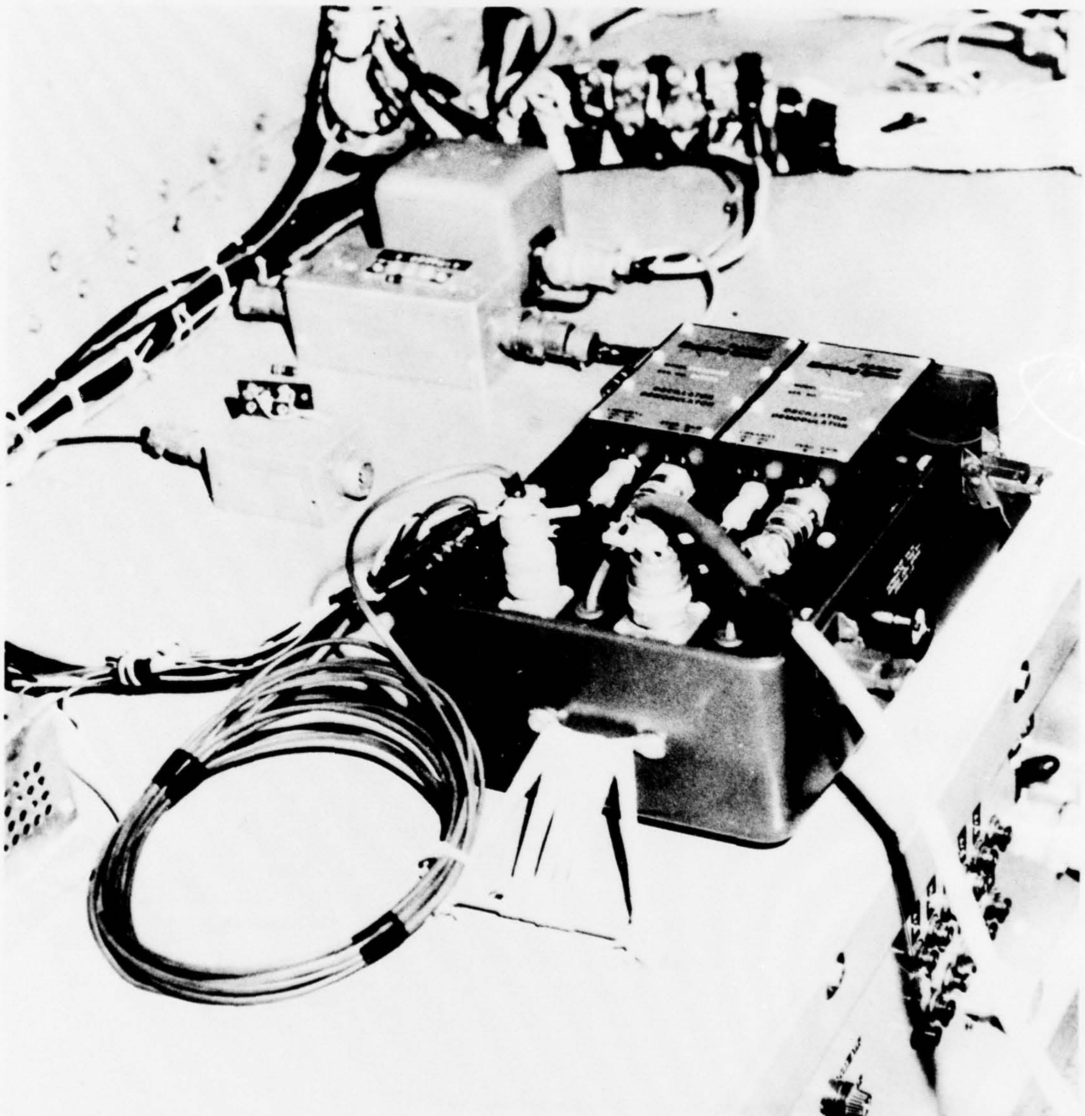


Figure C14. Power Supply/Demodulator Box.

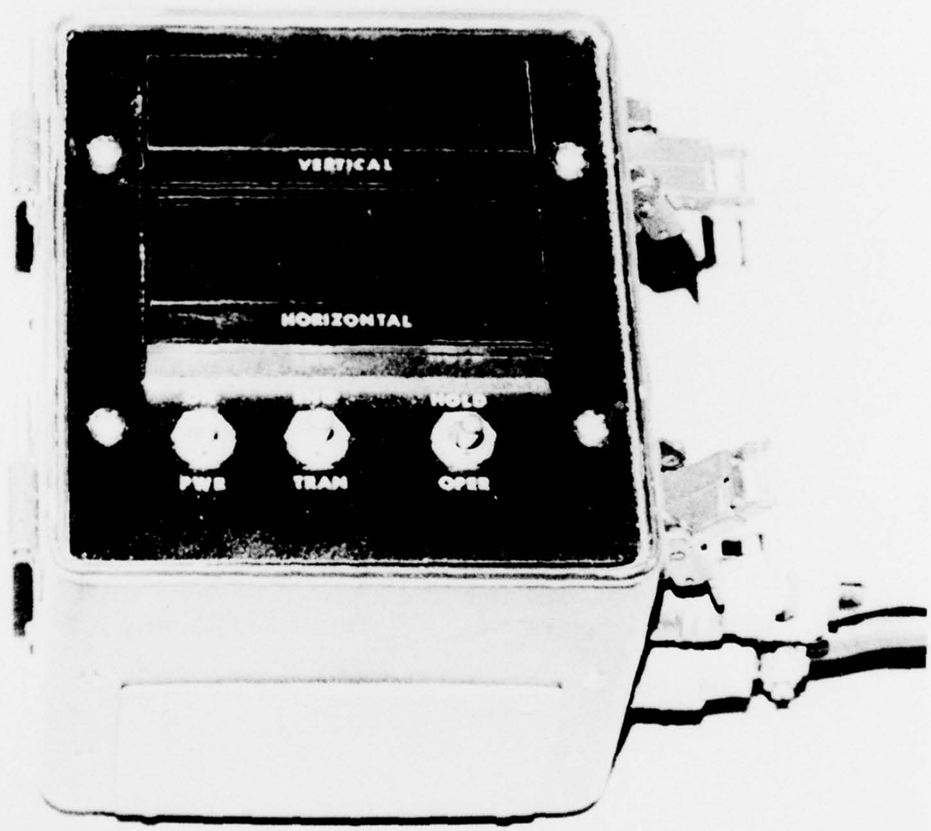


Figure C15. Digital Readout Box.

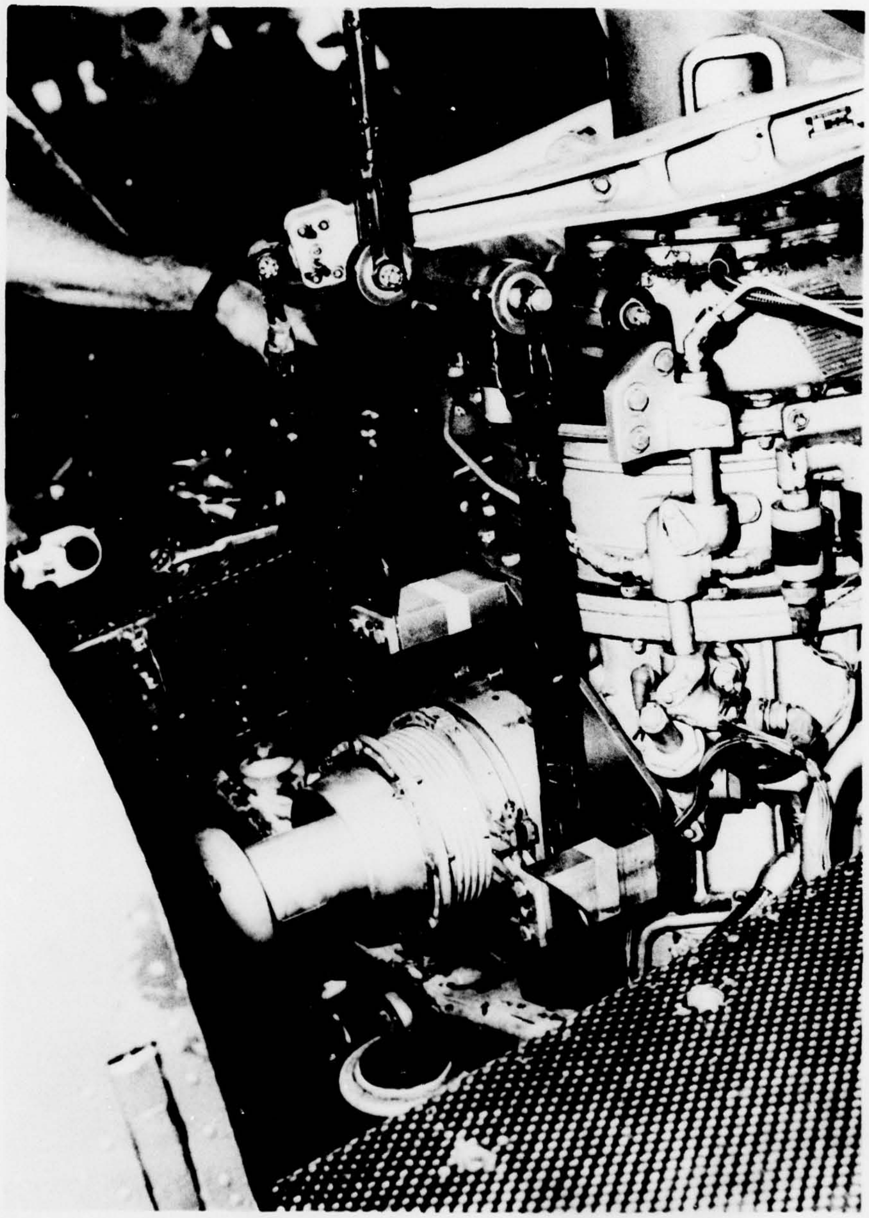


Figure C16. Mount Plate Installed, Particle Separator and Induction Baffle Removed.

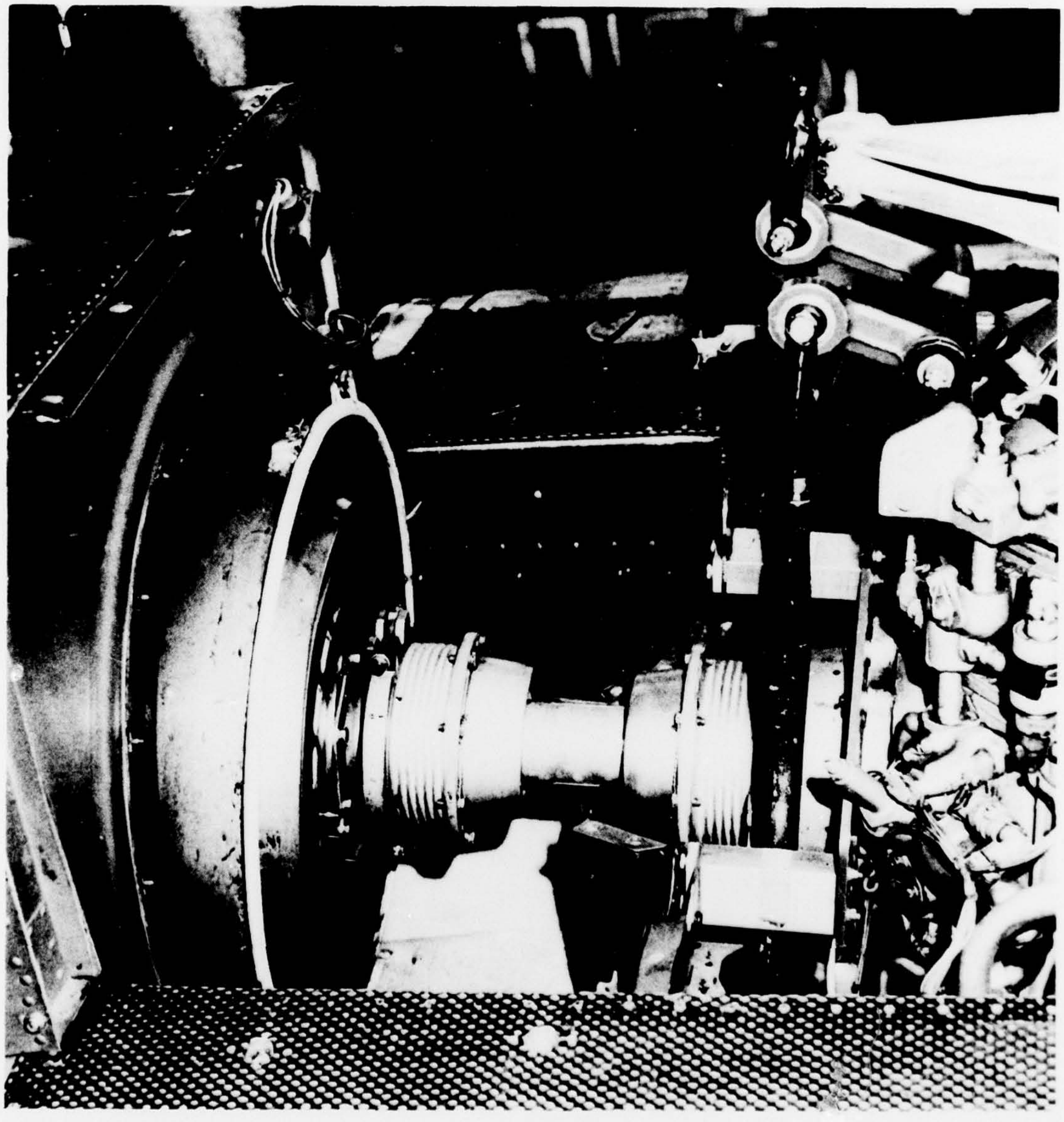


Figure C17. Lower Half of Modified Induction Baffle Installed.

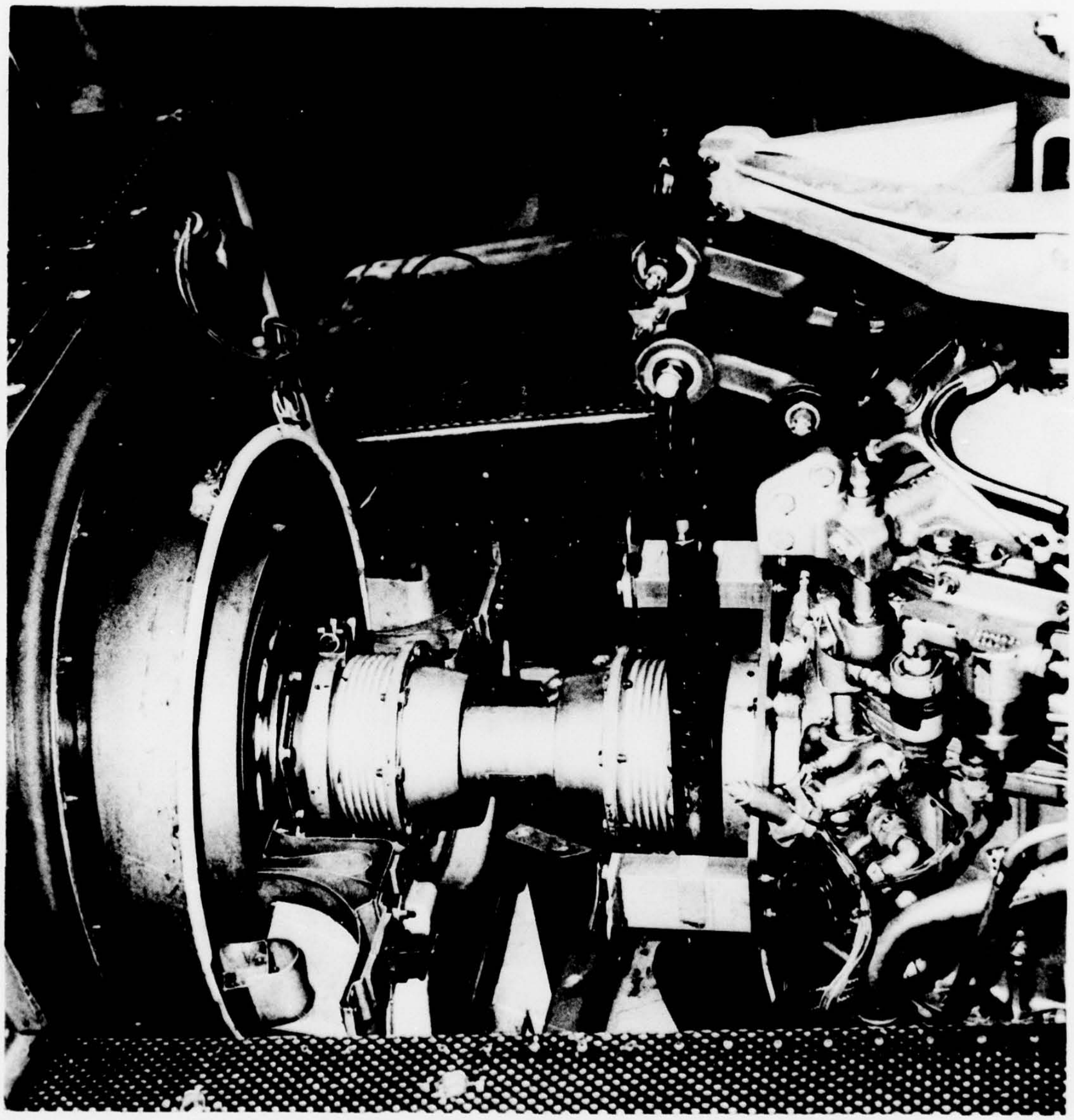


Figure C18. Lower Half of Particle Separator Installed.

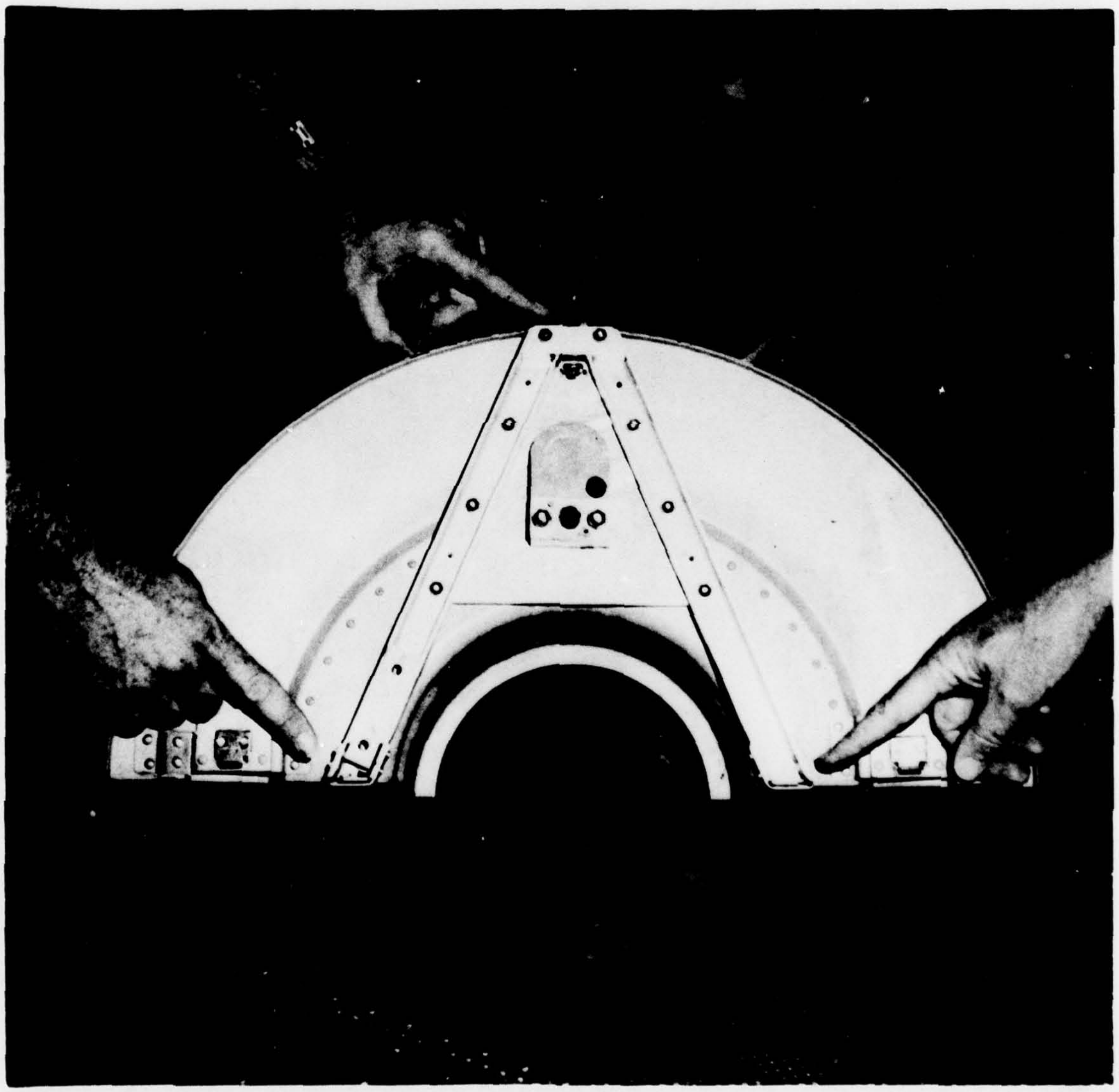


Figure C19. A-Frame Mounted on Upper Half of Particle Separator.

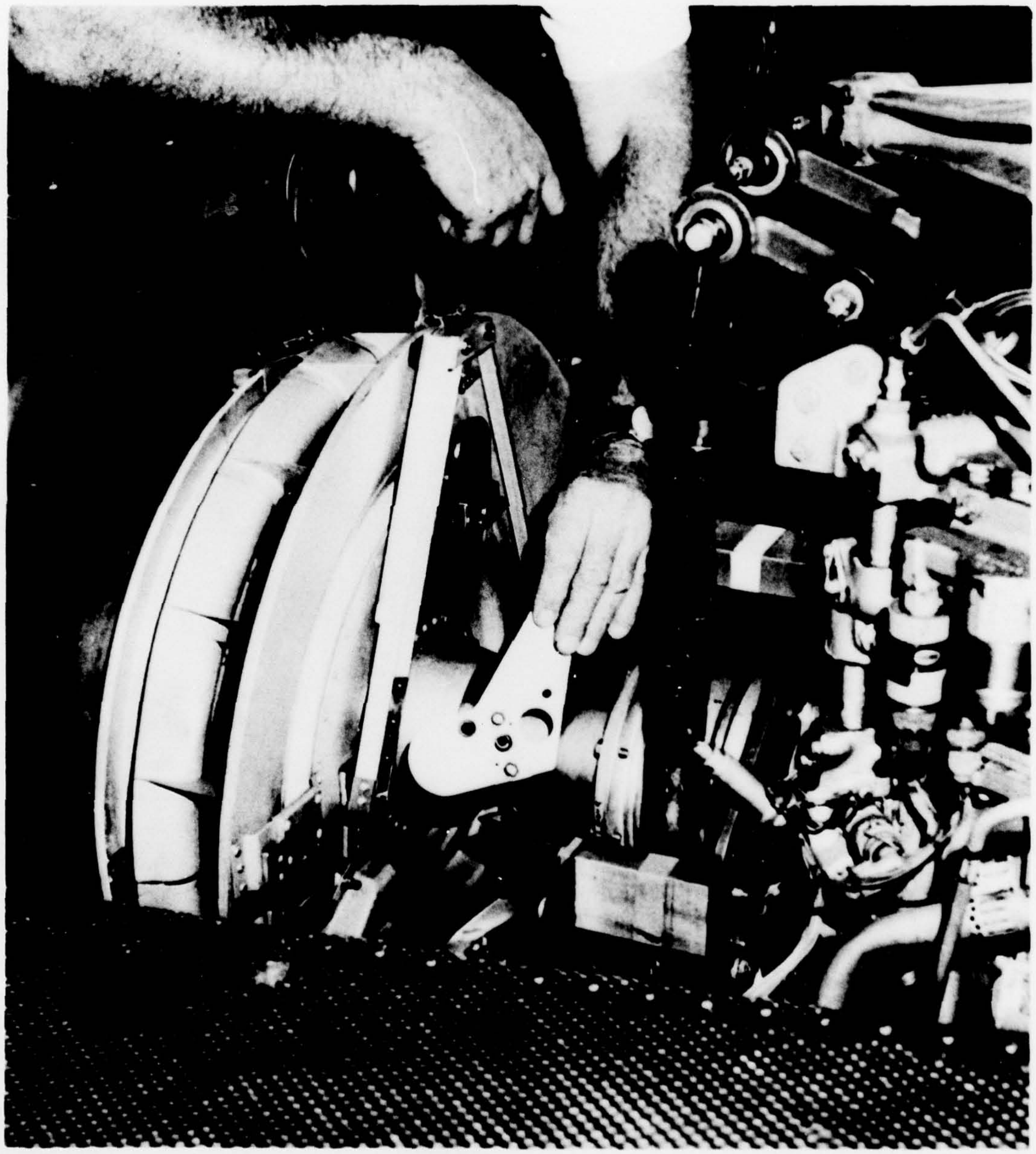


Figure C20. Particle Separator with A-Frame Installed, Dogleg Installation.

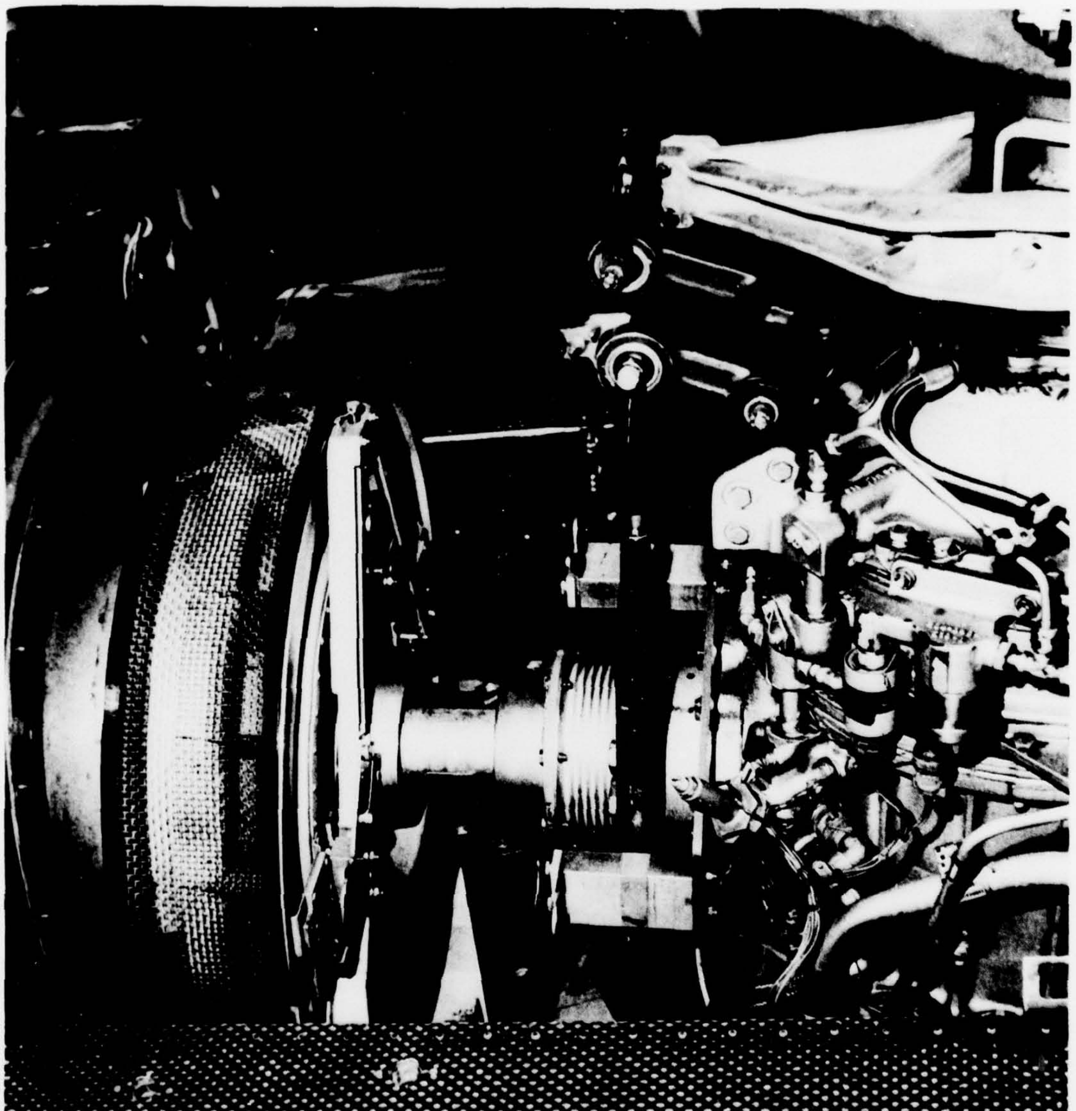


Figure C21. Top Screen Assembly Installed.

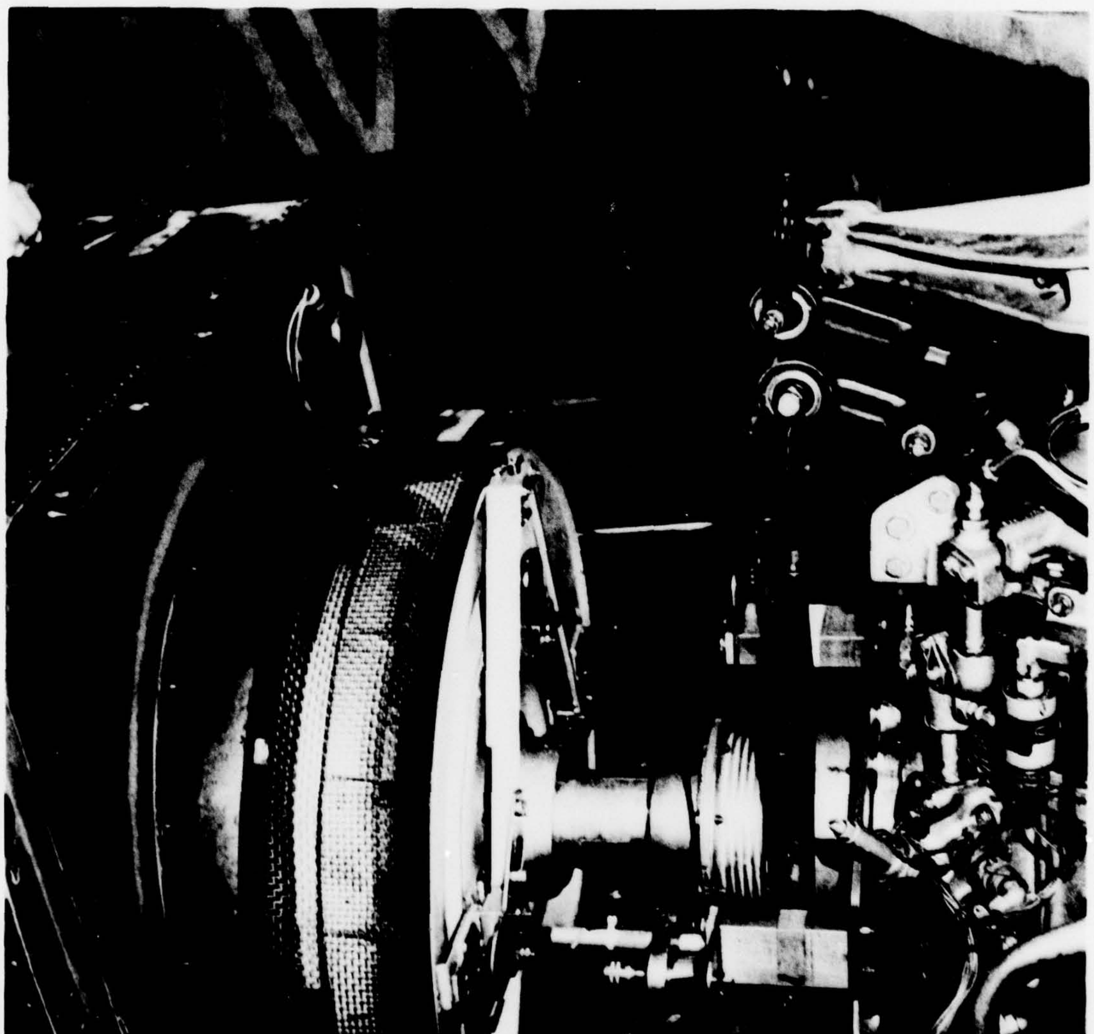


Figure C22. Horizontal Strut Assembly Installed.

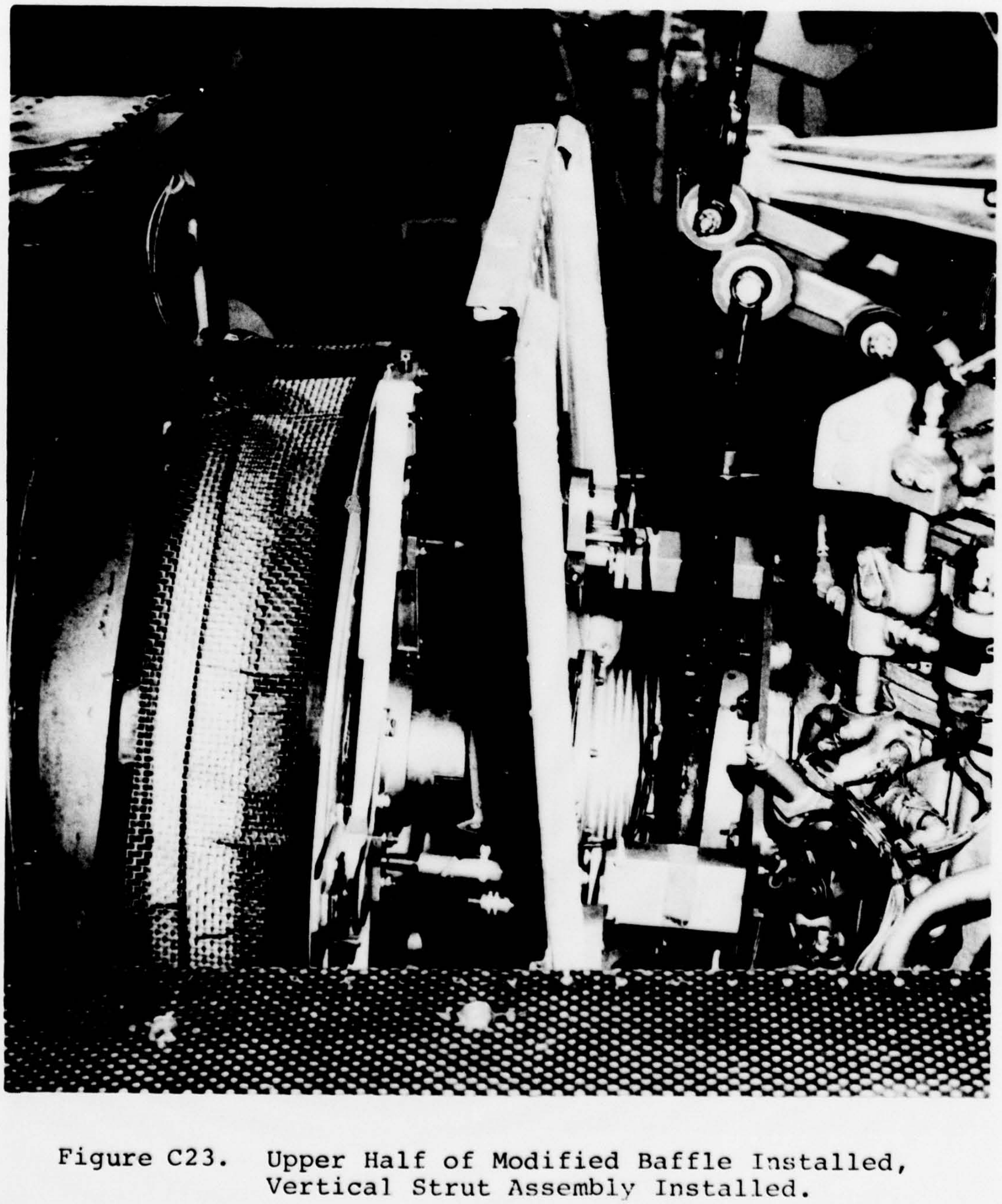


Figure C23. Upper Half of Modified Baffle Installed, Vertical Strut Assembly Installed.